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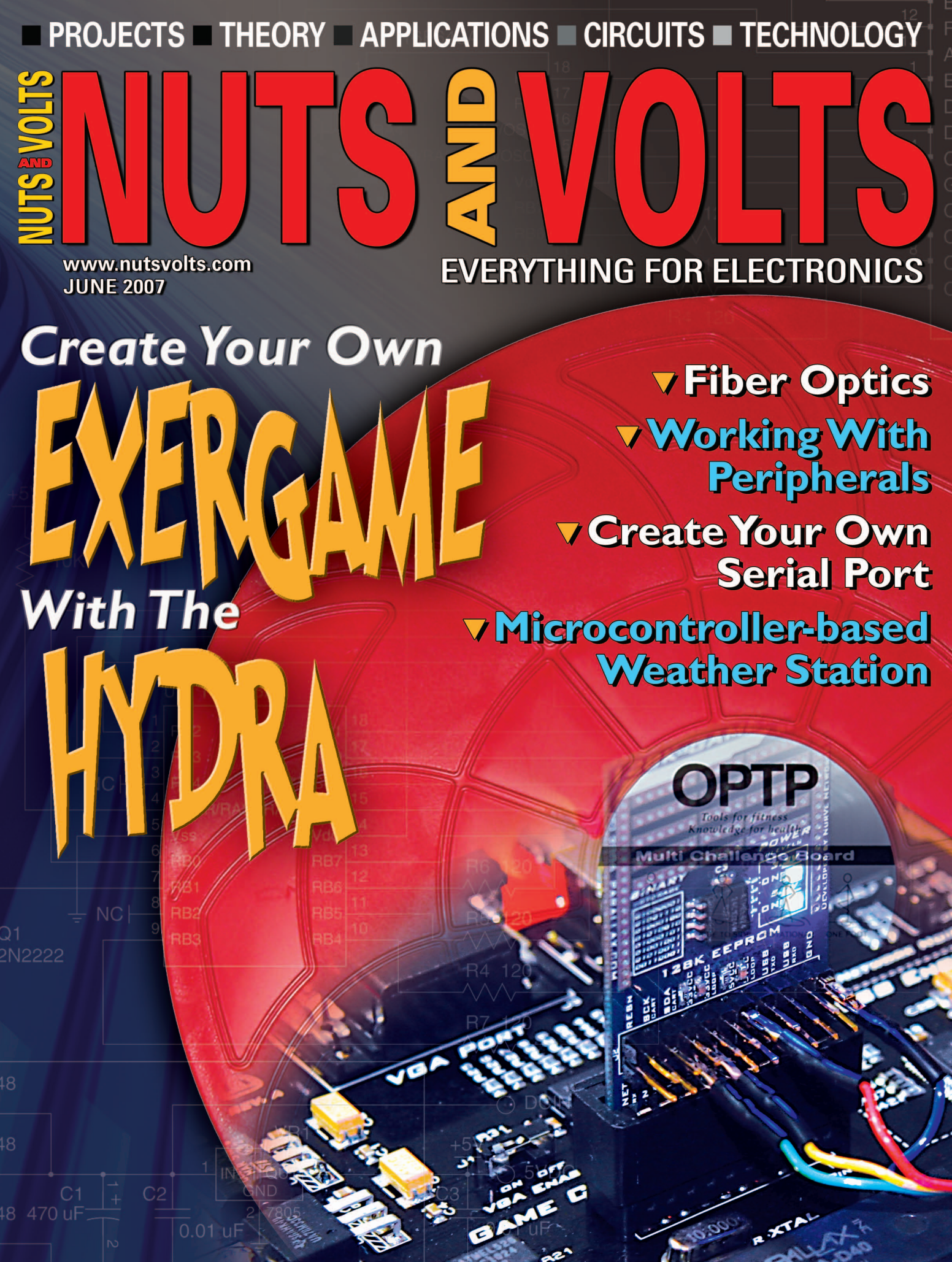
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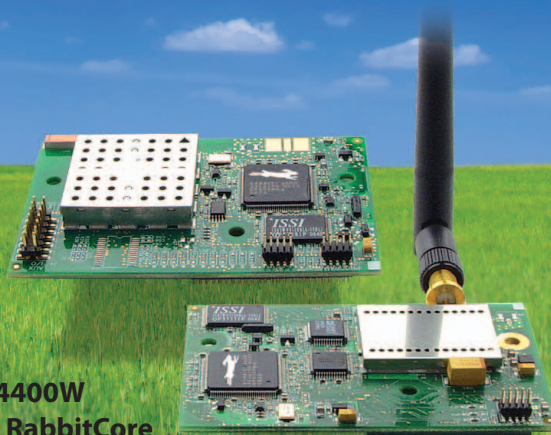
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JUNE 2007

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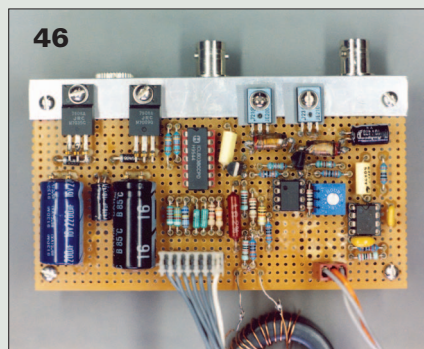
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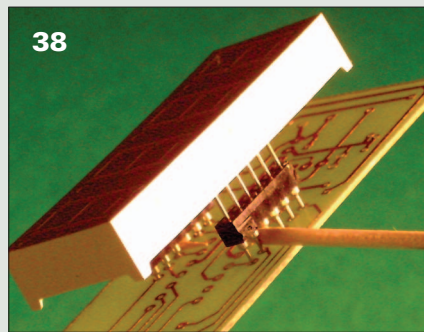
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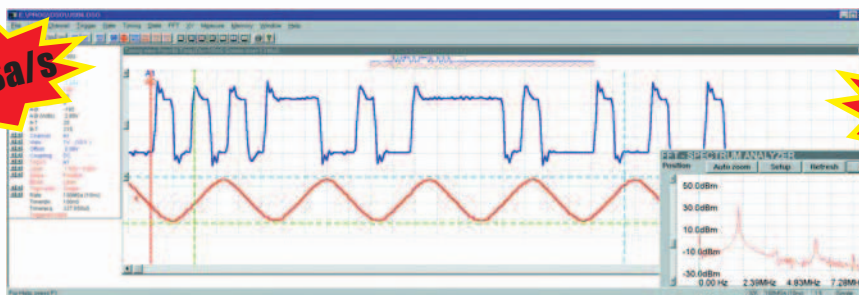
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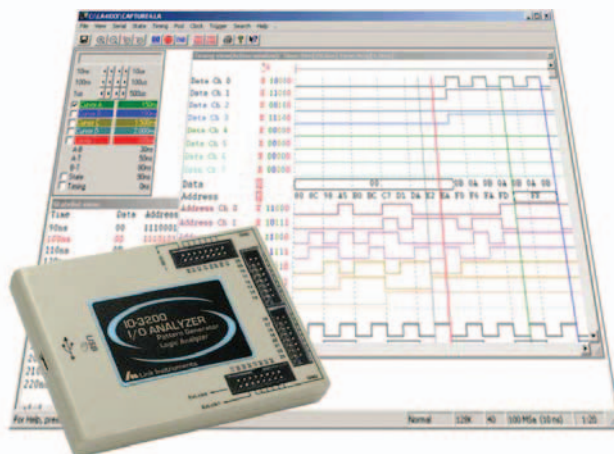


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by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

With the recent rise in global competition for technology and manufacturing jobs, professional associations, labor organizations, and political groups in the United States have begun to emphasize the need for innovation as a means of retaining and even expanding the domestic workforce. While many universities offer courses on innovation, it's not an ability that can be acquired by passively attending a lecture, reading a book, or surfing the Web. Furthermore, innovators aren't born. They develop their talents through active, directed, hands-on experience.

There is no one correct path to becoming an innovator. However, I've found experimenting with electronics, robotics, and microprocessors invaluable in developing the requisite skills, regardless of the areas in which innovation is eventually

applied. Designing a QRP transmitter, building a PID controller for a robot drive mechanism, and creating a smart appliance with a BASIC Stamp all involve creative problem solving, adherence to the scientific method, as well as time and resource management. Not only is experimenting with electronics an enjoyable avocation, but the fundamentals learned at the workbench can provide you with the foundation for innovation at work, school, and in your other pursuits.

Consider, for example, that there's no escaping the scientific method in the process of correctly diagnosing a circuit. Working systematically, you make a hypothesis about the functionality of a component, run tests to prove or disprove the hypothesis, and then, if necessary, move on to the next component or circuit. Like every good scientist or researcher,

you make notes about the process and your findings so that you'll be better able to recognize and address similar problems in the future. With experience, you'll become more proficient at diagnosis, and the process will become intuitive — integrated in your subconscious thinking.

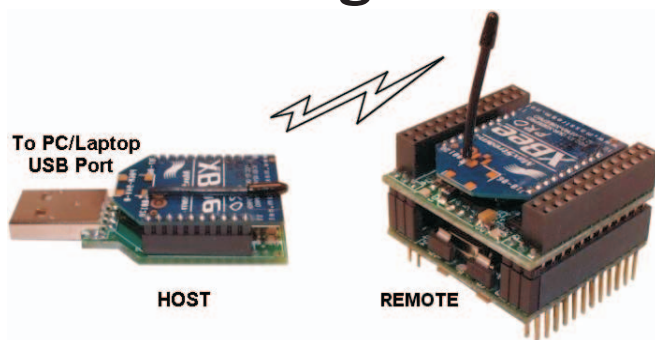
By mastering experimental fundamentals, you'll be in a better position to innovate. In this regard, innovation is a combination of logic and creativity — left and right brain activities that are normally at odds with each other. Intentionally shifting the balance between the logic and creativity will enable you to develop new circuits and devices in a controlled manner. Although it's possible to stumble upon a valuable discovery through random trial and error, relying on serendipity is at best a frustrating, inefficient, and low-yield alternative to directed innovation.

In the following pages are contributions from innovators spanning the fields of amateur radio, robotics, circuit design, microcontrollers, and fundamental electronics. As you read through the articles, you'll invariably encounter projects that either address a problem that you're facing or that simply peak your interest. Some articles will be more appealing to you than others, but they all provide building blocks upon which you can develop and practice innovation.

Whether your immediate goal is to explore the application of an electronic component, build test equipment that you otherwise wouldn't be able to afford, learn to program a new microcontroller, or provide your family with the added safety and convenience of a home automation project, you can make the most of the information provided by our authors by actively improving on it. Don't feel locked in to the descriptions or applications, but consider improving on the designs by making a calculated substitution here or a modification there so that the end result better suits your needs. That is, innovate, don't simply duplicate.

Now, turn to the article that most interests you, pick up your keyboard or soldering iron, and start innovating. **NV**

USB - XBee Dongle



Wireless serial links are easy now. The USB to XBee Dongle shown above hosts an XBee Pro 2.4GHz RF transceiver. It allows USB to remote XBee Pro ttl output serial communications at standard baud rates up to 115200 and ranges up to a mile. Dongle \$39. Kit with Dongle and 2 XBee Pro modules for \$111. Visit/call for details.

www.newmicros.com Tel:214-339-2204

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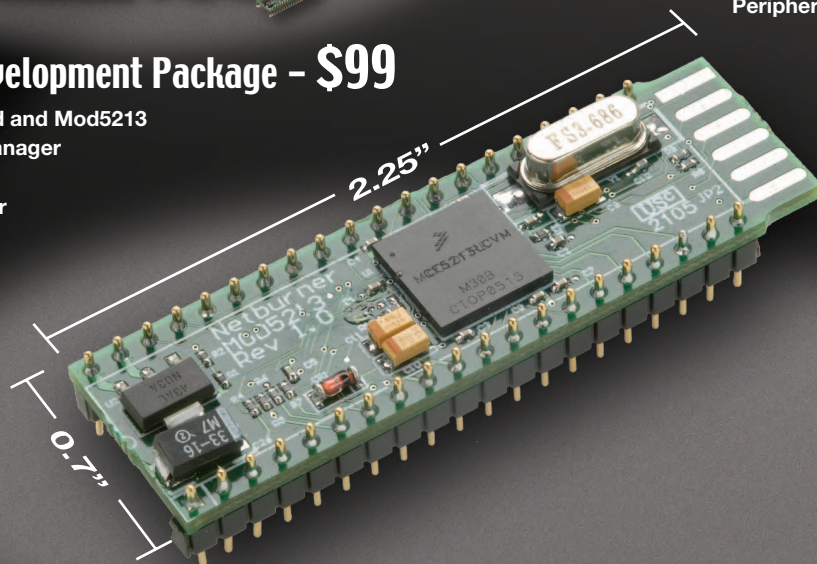
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READER FEEDBACK

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LOW DOWN ON THE DOWNLOAD

I would like to build the Digi-Log clock that was in the Feb '07 issue. However, the article does not tell me how to get the downloaded source code into the PIC. Please advise.

Norman Hockler

Response: Nuts & Volts, like many magazines that include software projects, does not list the code in the article for two basic reasons. The first is space. Some programs would require multiple pages to list. This is not cost-effective for the magazine. The second is speed and accuracy. Downloading a file is much simpler and more reliable than re-typing everything by hand. For these reasons I provide Nuts & Volts with the software and they provide it free of charge at their website, www.nutsvolts.com. The file in question can be located under the "FTP Index" associated with the issue and article. In this case, look at February 2007 and you'll see the "Clock.asm" file and a short description of the article with the title and author. Just click on the file name and the download will begin.

Once you download the file, you have

to program your PIC device. This requires significant software from Microchip, the manufacturer of the PIC microcomputer. The good news is that this sophisticated software suite is also free from their website at www.microchip.com. Again you will have to go to their website and locate the file associated with "MP-LAB."

Note: I provide the source code for all my projects. This is readable and can be easily changed. However, it needs to be compiled by the Microchip software before use (a simple command). Some others provide the object code. This does not need to be compiled but it still needs to be loaded into the Microchip software so that it can be copied into the PIC device. Object code is much harder to understand and/or change.

The last thing you will need is a programmer of some sort. This physically connects the PIC device to the MP-LAB software and it isn't free. I recommend the PIC-START, but it's a bit pricey now at \$199 (I think I got mine for about \$50 originally). It interfaces with their software well and supports virtually all of their products. There are probably hundreds of various other third-party "download cables" available that can cost under \$20. Most of these are fairly limited and not as easy to use. It may be possible to use one of Microchip's inexpensive development kits as a

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download cable. Check with a Microchip sales representative. This may seem like a lot of work. And for a single project, it certainly is. But few people use a microcomputer for only one project. Many users develop dozens or even hundreds of software ideas. Like any other endeavor, it takes some up-front investment in time and money to obtain the capability to use microcomputers. But once you do, there is a whole new world that opens up. I hope this helps.

Gerard Fonte

SEE MORE C8051F120 APPS

I am wondering if Mr. Best will be using the C8051F120 in a series of articles and what types of applications will be covered.

George Drouant

Response: Thanks for reading Design Cycle!

What you saw in the April and May Design Cycle columns will be taken a bit further one more time in this issue.

I will not cover any specific C8051F120 "applications." However, I will provide some additional practical coding examples that are intended to show off the bulk of the C8051F120's features while providing a leg-up to the prospective C8051F120 programmer. For instance, I'll provide code that will demonstrate the use of the C8051F120's Multiply and Accumulate module, as well as code to implement interrupt-driven RS-232 communications.

I hope you've enjoyed the C8051F120 stuff that has been offered up thus far. Again, thanks for taking time to read Nuts & Volts and the Design Cycle column.

Peter

CAN INVERTER(S) TAKE THE HEAT?

I enjoyed the article in the Dec '06 issue about furnace back-up. I plan to do this, but I need an explanation about inverters. I am confused about the specs mentioned. There seems to be quality issues with them. Maybe an article about inverters would be helpful.

My particular furnace has a 1/6 HP motor. The plate says seven amps input, 115V. (I calculate 805 watts.) I am looking at a Motor Trend brand sold through the Sportman's Guide mail order catalog. It is a 3,000 continuous/6,000 peak optimum efficiency 80%. I was thinking of also running a battery charger off of this to keep the battery charged. Any ideas? Help with this would be greatly appreciated.

Marc Krol


Response: Thank you for your feedback! I am always appreciative of anyone who drops me a nice note about what they are doing.

Your power calculation is probably fine; 805 watts (or 805 VA), is near enough

what your furnace requires to run. Actually, 1/6 HP is closer to 500 watts, but sometimes the current draw is based on a peak calculation, or perhaps your specification includes associated control


Continued on Page 45

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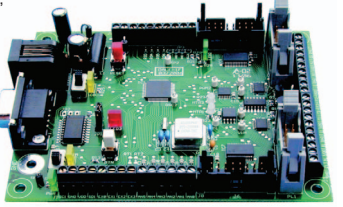
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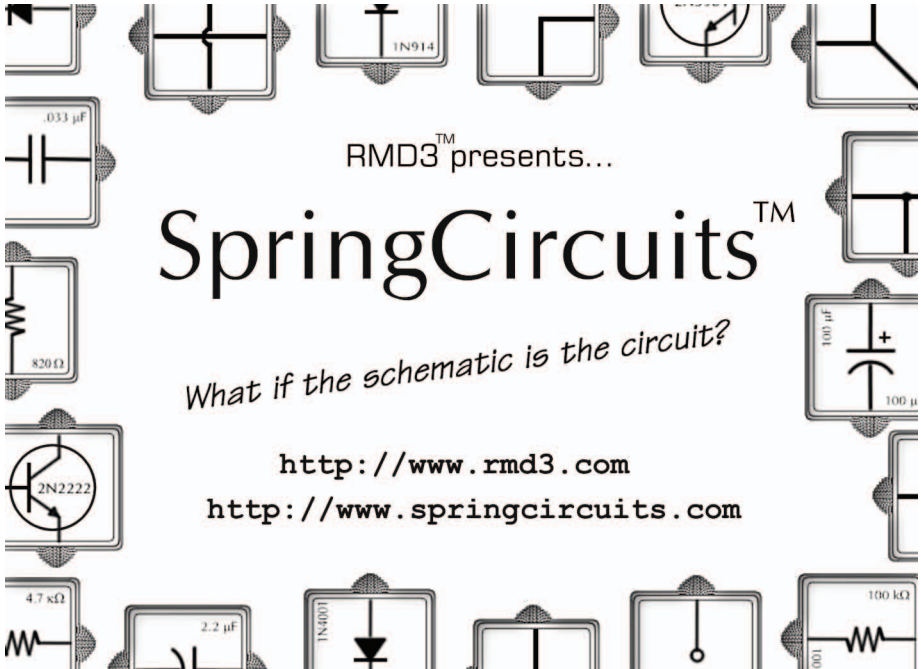


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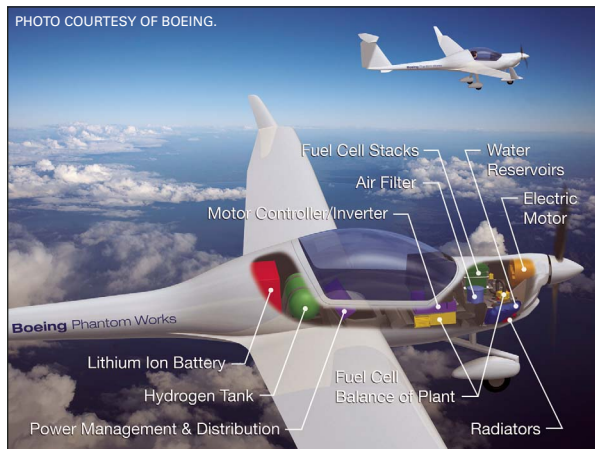


■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

FUEL CELL POWERED AIRPLANE TO BE DEMONSTRATED

PHOTO COURTESY OF BOEING.



■ Layout of the fuel cell powered airplane.

One of the most ambitious fuel cell projects out there is the Fuel Cell Demonstrator Airplane project, which actually began in 2003 at Boeing Research and Technology — Europe (BR&TE), a division of the Boeing Phantom Works (www.boeing.com/phantom). The project has now entered the demonstration phase. According to the company, “Given the efficiency and environmental benefits of emerging fuel cell technology, Boeing wants to be on the forefront of developing and applying it to aerospace products.”

The project involves fitting a modified Dimona glider, built by Austria’s Diamond Aircraft Industries (www.diamondair.com), with a Proton Exchange Membrane (PEM) fuel cell/lithium-ion battery hybrid system. The PEM runs an electric motor that provides all power for the cruise phase of flight. (The plane draws from only batteries during takeoffs and landings.) The airplane, with a wingspan of 53.5 ft (16.3 m), should cruise at about 62 mph (100 km/h). The flight tests, set to be conducted in Spain, are intended to demonstrate for the first

time that a manned airplane can maintain a straight level flight with fuel cells as the only power source. Although BR&TE does not predict that fuel cell technology will ever be suitable for large commercial airplanes, it could be practical for small manned and unmanned air vehicles.

HARVESTING BACKGROUND ENERGY

One of the challenges in the development of practical nanoscale devices has been how to power the things.

Batteries tend to be physically too large and, because they contain toxic substances, it is not always advisable to implant them in your body. But now researchers at Georgia Tech’s School of Materials Science and Engineering (www.mse.gatech.edu) have come up with a prototype nanometer-scale generator that can produce DC current by tapping into mechanical energy from such environmental sources as ultrasonic waves, mechanical vibration, and blood flow.

The device is based on an array of

■ Schematic showing the DC nanogenerator using ZnO nanowire arrays with a zigzag electrode.

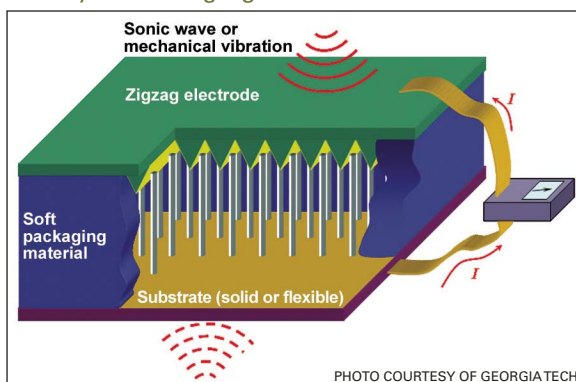


PHOTO COURTESY OF GEORGIA TECH.

vertically aligned zinc oxide nanowires, located about 0.5 m apart on a substrate of gallium arsenide, sapphire, or flexible polymer. When vibrations strike the exterior, the wires move within a “zigzag” plate electrode to produce power, taking advantage of the coupled piezoelectric and semiconducting properties of zinc oxide nanostructures, which produce small electrical charges when they are flexed.

The power generated is only in the nanoampere range, but that should be enough to run a range of tiny devices, thus eliminating the need for batteries or external power. It is projected that an optimized version could produce up to 4 W/cc, which would be enough to make it useful in defense, environmental, and (because zinc oxide is nontoxic) biomedical nano devices, including biosensors, environmental monitors, and nanoscale robots.

COMPUTERS AND NETWORKING

EIGHT-CORE MAC INTRODUCED

So far, 2007 has not produced a cornucopia of computer hardware innovations, but Apple (www.apple.com) has upgraded its line of Mac Pro desktops to include an eight-core version. The top model

includes dual quad-core Intel Xeon “Clovertown” processors running at 3.0 GHz, as opposed to the lesser ones that offer two dual-core “Woodcrest” chips running at 2.0, 2.66, or 3.0 GHz. The box has four hard drive bays providing up to 3 TB of internal storage, and you can install as much as 16 GB of main memory. The options are too numerous to mention,

■ The latest Mac Pro model features dual quad-core Xeon processors. PHOTO COURTESY OF APPLE, INC.

with up to 33 million possible configurations of the system. But the eight-core box is said to run up to twice as fast as the G5 quad, so if you need the extra crunching power, here it is. The new model will set you back at least \$3,997, plus whatever extras you choose.



without using a browser. All in all, Yahoo! is offering more than 3,400 desktop Widgets developed and submitted by independent authors from around the world. Best of all, it's free and runs on Mac OS X, Win 2000, Win XP, and Vista.

BE CAREFUL WHAT YOU GOOGLE

Back in 2003, New Jersey prosecutors charged Melanie McGuire with first degree murder, desecrating human remains, possession of a weapon for an unlawful purpose, and perjury after her husband, William McGuire, was found shot, dismembered, divided among three suitcases, and floating in the Chesapeake Bay. Although not all the evidence has been made public, data gleaned from several seized computers showed that Melanie did a Google search on "how to commit murder" 10 days before the crime. She also scanned the Web for such phrases as "undetectable poisons," "fatal insulin doses," "where to purchase guns illegally," and "how to find chloroform." She faces 30 years to life if convicted, and hopefully some extra time for computer illiteracy.

CIRCUITS AND DEVICES

BINOCULARS WITH DIGITAL CAMERA

PHOTO COURTESY OF CELESTRON.



■ The VistaPix combines 8x magnification, fully coated lenses, and three megapixel resolution.

picture, buddy. It'll last longer." Well, now you can, and from a safe distance. Several manufacturers of binoculars are now combining them with a digital camera, so no matter what kind of a birdwatcher you may be, you can record noteworthy sightings for posterity and/or the Internet with total discretion. You can pick up a set at Wal-Mart for about \$50, but be advised that this will get you resolution as poor as 0.3 megapixels, which isn't exactly high-res. But if you are willing to shell out something closer to real money, you can get both quality optics and high digital resolution.

One example is the VistaPix 8 x 22 from Celestron, LLC (www.celestron.com). It starts out with a basic 8 x 22 system and adds a three megapixel camera with a 1.5-in flip-up color LCD screen for previewing images. The LCD offers a 6x digital zoom so you can look at details, and a removable 8x telephoto lens allows you to take close-up or high-magnification shots. In addition to still photos, you can do sound-enabled video captures, making movies of up to three minutes in length. And just for the heck of it, Celestron even threw in an FM radio with earphones. The list price of \$251.95 seems pretty reasonable. Why didn't someone think of this sooner?

NEW COLOR INSPECTION SYSTEM

Banner Engineering Corp. (www.bannerengineering.com) has introduced a pair of vision sensors that, although not particularly useful in the average home, could come in handy if you are involved in visible spectrum analysis on a commercial level in such fields as packaging, pharmaceuticals, and general

■ Accused Google murderer Melanie McGuire.

■ The new Flickr Widget extends Yahoo!'s photo-sharing service.



Sooner or later, every male of the species admires a female a moment beyond what is totally prudent, resulting in the dreaded, "Take a

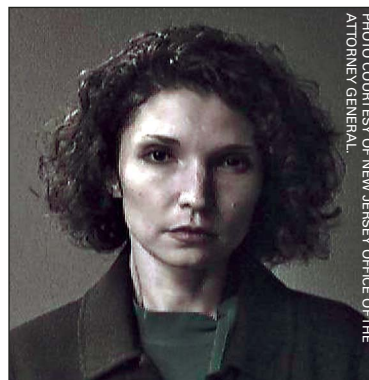


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Source Code: NVM50



PHOTO COURTESY OF BANNER ENGINEERING.
■ The PresencePLUS® vision sensors detect an infinite number of color variations.

quality control applications. Examples include inspection of candy and packages, blister packs, filled bottles, and so on.

The two-piece PresencePLUS Pro includes a separate DIN-mountable controller, whereas the P4 is a one-piece unit. Both are said to detect an infinite number of color variations accurately, and the sensor can combine shape and color data to detect even minute variations.

Both models come with the company's universal software with three-step point-and-click setup; Ethernet, serial, and discrete I/O capabilities; live video display without the need of a PC; and a selection of lenses, light sources, mounting brackets, and accessories. The systems run

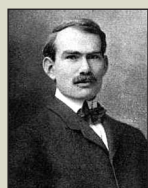
off 10 to 30 VDC and are available with interfaces in nine different languages. Prices start at about \$3,500.

LITHIUM BATTERIES PACK BIG CHARGE

Tadrian Batteries Ltd. (www.tadrianbat.com) now offers a line of lithium cells for applications requiring high power, long life, and extended storage, such as defibrillators and other portable medical devices, mil/aero systems, telemetry, and UAVs, and so forth. The newly introduced AA-size TLM 1550 provides 2 Wh of energy at 4.0V and the ability to handle pulses of up to 15A and continuous loads of 5A.

It is designed for long life in extreme environmental conditions (-40 to +85°C) and features a self-discharge rate of only three percent per year at room temperature. Because the cells are built with a glass-to-metal hermetic seal and nontoxic and nonpressurized solvents, they can be shipped as nonhazardous. The quantity price is said to be about \$5 each, which is a bit more than the average Ray-O-Vac, but may be worth the money to keep your digital camera from fuzzing out in the middle of your next hike through the Grand Canyon. **NV**

INDUSTRY AND THE PROFESSION 100TH ANNIVERSARY

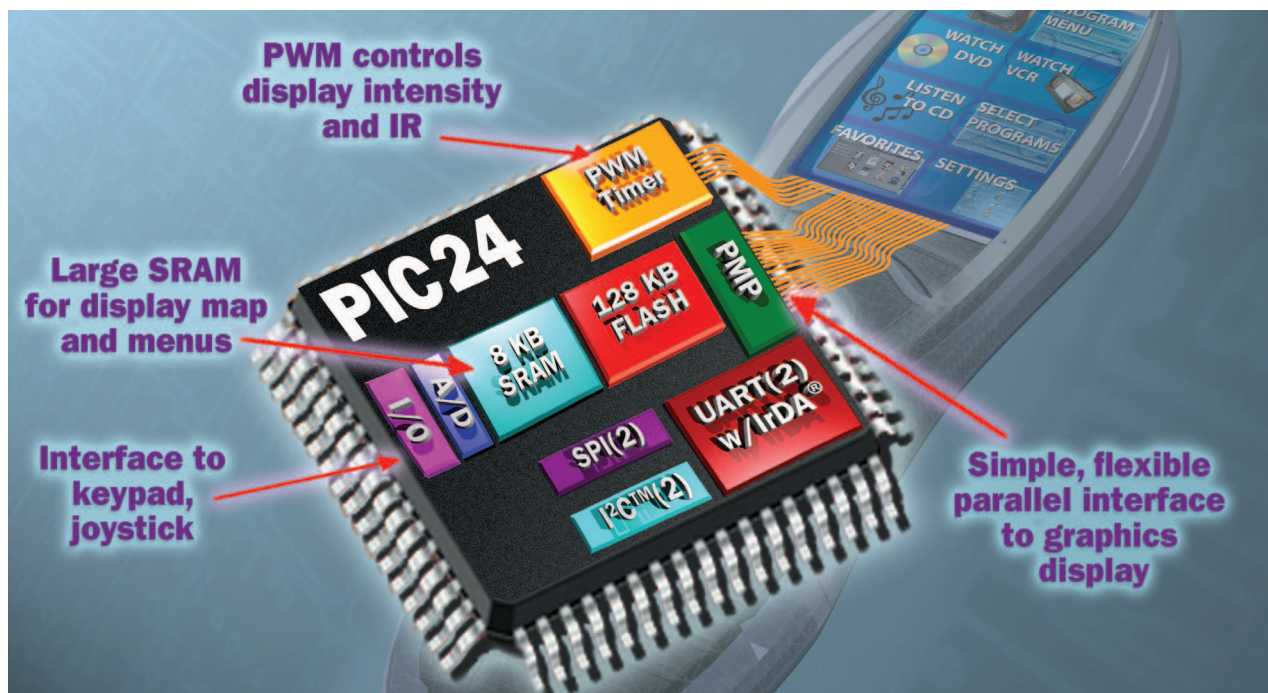


■ Inventor Lee De Forest (public domain photo).

In case you haven't kept up with such things, 2007 marks the 100th anniversary of the invention of the three-electrode version of the Audion vacuum tube that allowed amplification for radio reception. It was also called the De Forest valve until about 1919, since which time it has been better known as the triode. Perhaps more interesting is the inventor, Lee De Forest, who apparently was a colorful fellow. On the positive side, he earned a doctorate

from Yale, held more than 300 patents, and was a charter member of the Institute of Radio Engineers (a predecessor of today's IEEE). However, legend has it that he did not even understand how his own invention worked (and, in fact, his prototypes did not work), and another inventor, Edwin Armstrong, had to explain its operating principles to De Forest. He wrote an autobiography called Father of Radio, although most of the world did not recognize him as such. During his career, he presided over several companies that failed, was once indicted (and acquitted) for mail fraud, and was involved in several patent lawsuits that nearly bankrupted him. In 1913, he was forced to sell the triode patent to AT&T at a bargain basement price. De Forest went to that big vacuum tube in the sky in 1961.

Control Your Remote with Low-Cost 16-bit MCUs



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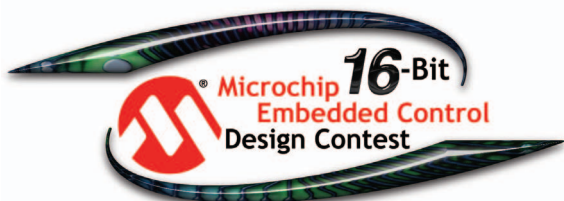
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Device	Pins	Flash (KB)	PIC24F Family Features
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PIC24FJ64GA008	80	64	Parallel Master Port
PIC24FJ64GA010	100	64	5 - 16-bit Timers
PIC24FJ96GA006	64	96	5 - Output Compare/PWM
PIC24FJ96GA008	80	96	5 - Input Captures
PIC24FJ96GA010	100	96	Real-Time Clock Calendar
PIC24FJ128GA006	64	128	2 - UART with IrDA® and LIN Protocols
PIC24FJ128GA008	80	128	2 - SPI, 2 - I ² C™
PIC24FJ128GA010	100	128	10-bit ADC, 16 Channels
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- ✓ Monitors the entire aircraft band without tuning!
- ✓ Passive design, can be used on aircraft, no local oscillator, generates and creates no interference!
- ✓ Great for air shows
- ✓ Patented circuit and design!

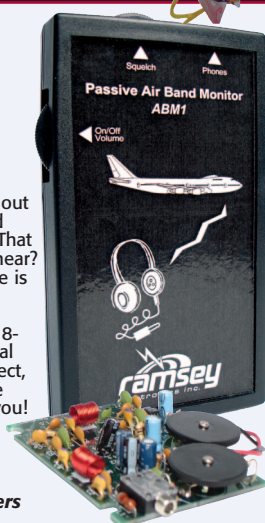
For decades we have been known for our novel and creative product designs. Well, check this one out! An aircraft receiver that receives all nearby traffic without any tuning. It gets better... there is no local oscillator so it doesn't produce, and can't produce, any interference associated with all other receivers with an LO. That means you can use it onboard aircraft as a passive device! And what will you hear? The closest and strongest traffic, mainly, the plane you're sitting in! How unique is this? We have a patent on it, and that says it all!

This broadband radio monitors transmissions over the entire aircraft band of 118-136 MHz. The way it works is simple. Strongest man wins! The strongest signal within the pass band of the radio will be heard. And unlike the FM capture effect, multiple aircraft signals will be heard simultaneously with the strongest one the loudest! And that means the aircraft closest to you, and the towers closest to you! All without any tuning or looking up frequencies! So, where would this come in handy?

1. At an air show! Just imagine listening to all the traffic as it happens
2. Onboard aircraft to listen to that aircraft and associated control towers
3. Private pilots to monitor ATIS and other field traffic during preflight activities (saves Hobbs time!)
4. Commercial pilots to monitor ATIS and other field traffic as needed at their convenience
5. General aircraft monitoring enthusiasts

Wait, you can't use a radio receiver onboard aircraft because they contain a local oscillator that could generate interfering signals!

We have you covered on that one. The ABM1 has no local oscillator, it doesn't, can't, and won't generate any RF whatsoever! That's why our patent abstract is titled "Aircraft band radio receiver which does not radiate interfering signals". It doesn't get any plainer than that! Available as a through-hole hobby kit or a factory assembled & tested SMT version.



SPECIFICATIONS

Frequency Range:	118 MHz to 136 MHz
Receiver Type:	Patented Passive Detector
IF Frequencies:	None!
Receiver Sensitivity:	Less than 2 uV for detectable audio
Audio Output:	700mW, 8-24 ohms
Headphone Jack:	3.5mm stereo phone
External Antenna:	Headphone cord coupled 9VDC battery
Power Requirement:	2.25" x 2.8" PC Board
Dimensions:	2.25" x 4.6" x .9" Case
Weight:	4 oz. with battery

ABM1 Passive Air Band Monitor Kit

ABM1WT Passive Air Band Monitor, Factory Assembled & Tested

\$89.95

\$159.95

Digital Tuned High Performance Aircraft Band Receiver

- ✓ Rock solid dual conversion PLL receiver!
- ✓ Airport runway lighting controller output!
- ✓ 4 user memory scanner banks, 20 freq's each
- ✓ Full band scanner with skip and skip/timer modes
- ✓ Internal front panel speaker
- ✓ External antenna input, speaker out, headphone out
- ✓ Stylish and shielded black metal enclosure
- ✓ Available as a hobby kit or factory assembled & tested

Professional features at a hobbyist price! To begin with, we designed it with the latest technology, utilizing a rock stable synthesized PLL dual conversion receiver. We gave it superb image and adjacent channel rejection to allow you to lock onto the signals you want and not to be bothered by those you don't!

Once we got the RF portion designed we took a close look at the features desired in such a receiver. We gave it a neat 2x8 line LCD display to show you all the functions. Control of modes and setups is obtained through the front panel controls and confirmed on the LCD display. On/Off/Volume and Squelch controls are also provided on the front panel. We even gave it a front panel speaker in case you stack the lighting controller or something else on top of it! So far we've described the ultimate aircraft receiver that's not only the perfect field monitor for a hangar or airport manager's office, but for the serious enthusiast. Can it get any better than that? It sure can!

The top request we've had for a professional aircraft receiver was to embed automatic runway lighting control. Consider it done! The lighting controller follows the standard protocol for remote runway lighting. The pilot "keys" his microphone on the local CTAF channel for the specified number of times. All you need to do is set the receiver for the lighting control mode, then make sure the squelch is closed and will open on a suitably strong signal. Typically the number of "keys" or "events" according to the receiver control the lighting as follows: 3 events, 25% brightness; 5 events, 50% brightness; and 7 events, 100% brightness. The AR2's adjustable lighting timer sets turn-on duration to your needs. Includes the matching case and knob set and power supply. For the aviation professional that is not interested in building the receiver, the AR2 and the lighting controller are also available factory assembled and tested, ready to go. Just plug it in and you're all set.

SPECIFICATIONS

Frequency Range:	117.975 MHz to 137.000 MHz
Receiver Type:	25kHz Conversion
IF Frequencies:	Dual Conversion PLL
Receiver Sensitivity:	10.7 MHz & 450 kHz
Image Rejection:	Less than 1 uV across the band
Adjacent Ch. Rejection:	Greater than -80 dB
Scanner Banks:	Greater than -40dB
Audio Output:	4, 20 frequencies each
Light Controller Output:	1 watt, 8 ohms
Power Requirement:	3 events, 5 events, 7 events
External Antenna:	output to controller
Dimensions:	12VDC, 500mA
	BNC female, rear panel
	5.55"W x 6.45"D x 1.5" H

AR2 Synthesized Aircraft Receiver Kit With Case & AC Power Supply

AR2WT Factory Assembled & Tested AR2 Synthesized Aircraft Receiver

AR2L Plug-In Runway Lighting Controller Interface Kit With Case & AC Power Supply

AR2LWT Factory Assembled & Tested AR2L Runway Light Controller

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Top Picks... Just for Them!

Digital FM Stereo Transmitter



For nearly a decade we've been the leader in hobbyist FM radio transmitters. The FM30 series of transmitters is the latest and greatest! We told our engineers we wanted a new technology transmitter that would provide FM100 series quality without the advanced mixer features. They took it as a challenge and designed not one, but TWO transmitters! The FM30 is designed using through-hole technology and components and is available only as a do-it-yourself kit, with a 25mW output very similar to our FM25 series.

Then the engineers redesigned their brand-new design using surface mount technology (SMT) for a very special factory assembled and tested FM35WT version, with 1W output for our export only market! Both are designed around an RF tight vinyl clad metal enclosure for noise free and interference free operation.



All settings can be changed without taking the cover off! Enter the setup mode from the front panel and step through the menu to make all of your adjustments. A two line LCD display shows you all the settings! In addition

to the LCD display, a front panel LED indicates PLL lock so you know you are transmitting. Besides frequency selection, front panel control and display gives you 256 steps of audio volume (left and right combined) as well as RF output power. A separate balance setting compensates for left/right differences in audio level.

In addition to settings, the LCD display shows you "Quality of Signal" to help you set your levels for optimum sound quality. And of course, all settings are stored in non-volatile memory for future use! The stylish black metal case measures 5.55"W x 6.45"D x 1.5"H. Runs on 13.8-16VDC, plug-in 110VAC power supply included.

(Note: The end user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body. FM35BWT is for export use and can only be shipped to locations outside the continental US or valid APO/FPO addresses or valid customs brokers for end delivery outside the continental US).

FM30B FM Stereo Xmtr Kit \$199.95
FM35BWT FM Stereo Xmtr Export \$299.95

3-In-1 Multifunction Soldering Lab

Take a close look! On your left is a multifunction 3 1/2 digit digital multimeter. Its large backlit LCD display can be seen from anywhere on your bench while you're working. The DMM also features built-in transistor, diode, and continuity testing, data hold, and audible alarm. Next up, the regulated lab DC power supply. Switch selectable ranges of 3V, 4.5V, 6V, 7.5V, 9V, and 12V provide a continuous duty current of 1.5 amps with a 2 amp peak! Features both overload protection and overload indication.

To the right we have a high quality temperature regulated soldering station. The 24V low voltage iron features an isolated ceramic 48 watt temperature controlled element. Front panel control gives you variable tip temperature control from 150°C to 450°C and LED indication of power-on and heating-on. Runs on 120VAC.

LAB1U 3-In-1 Soldering Lab \$119.95

High Resolution Air Pressure & Elevation Sensor



- ✓ Pressure resolution greater than 0.0001kPa!
- ✓ 128 x 64 pixel graphical display!
- ✓ Shows realtime elevation & pressure changes!
- ✓ USB computer interface for easy data transfer!
- ✓ 13,824 samples of FLASH storage available!
- ✓ Special pilots menu
- ✓ Multiple built-in alarms

What The Customer's Are Saying... "Simply Stunning!"

We really did it this time! The UP24 is one of our most advanced kits to date, and an absolute MUST for anyone serious about the environment around us. But the applications only begin there!

The unique design allows unprecedented super high resolution measurements and display of absolute atmospheric air pressure. The UP24 senses ambient air pressure and critically calculates elevation with unheard of precision! Using a highly sensitive sensor and 24-bit A/D converter in a special noise-immune design, less than 1/3 of an inch of elevation resolution is achieved! **YES, we said 1/3 of an inch!**

This high accuracy and resolution opens the door to a host of sophisticated environmental air pressure monitoring applications.

Unlike your normal run-of-the-mill barometer, air pressure is sensed in Pa's or kPa's. What are those you may ask? Pascals or KiloPascals. However, don't be afraid, for your convenience, and to fit any application you may have, it is also displayed in millibars, bars, PSI, atmospheres, millimeters of mercury, inches of mercury, and feet of water! Take your pick! The range of the UP24 is 15kPa to 155kPa. And that also means:

- ✓ 15000 to 155000 Pascal's
- ✓ 150 to 1550 Millibars
- ✓ 0.15 to 1.55 Bars
- ✓ 2.175566 to 22.48085 Pounds per square inch
- ✓ 0.1480385 to 1.529731 Atmospheres
- ✓ 112.5093 to 1162.596 Millimeters of mercury
- ✓ 4.429498 to 45.77148 Inches of mercury
- ✓ 5.02 to 51.9 feet of water

We've talked about air pressure, now let's talk about elevation! The incredibly precise 24 bit A/D converter in the UP24 looks at the air pressure and converts it to elevation above sea level. In both graph and text, the elevation is displayed to a resolution of a third of an inch!

The applications for the super accurate elevation meter are endless. From watching and recording elevations during hiking trips to measuring and recording the wave heights from your boat! Let your imagination take over from there!

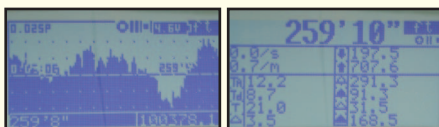
What if you're in the field and you want to save data captured in your UP24? The built-in FLASH storage provides 13,824 samples of storage. Then you can transfer your data to your PC with a standard USB interface.

While the UP24 is small enough to be kept in your coat pocket it boasts a large 2.78" x 1.53" 128x64 pixel LCD display screen making viewing easy. Display modes include both realtime pressure and elevation graphs as well as pressure and elevation statistics.

There are 12 user selectable sample rates from 1/10th of a second all the way up to every 15 minutes. Includes a built-in NiMH battery pack for up to 4 days of continuous use. 110VAC charger is included. May also be charged from a 6-12VDC source.

Needless to say, you cannot put all the specs and all of the screen shots in the limited space of this ad! Just check out the Elevation and Air Pressure displays below! For detailed information and specs visit our website at www.ramseykits.com.

If you're looking for the finest air pressure and elevation sensor, check out the UP24, truly a marvel in the industry! Available in a ready-to-build kit or a factory assembled and tested version that you can start using right out of the box.



Elevation Graph

Elevation Statistics



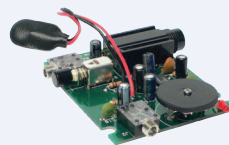
Air Pressure Graph

Air Pressure Statistics

UP24 High Resolution Air Pressure/Elevation Sensor Kit
UP24WT Factory Assembled and Tested UP24

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Personal Practice Guitar Amplifier & DI



- ✓ Practice your guitar or bass without disturbing others!
- ✓ Standard 1/4" guitar audio plug input
- ✓ CD/MP3 player audio headphone input to practice to your favorite music!
- ✓ Switchable bass boost!
- ✓ Great as a DI to your home stereo amplifier!
- ✓ Uses standard 9V battery
- ✓ Includes guitar strap/belt clip case!

So you're a guitar musician, and you live in an apartment...what else needs to be said! You would love to plug into your 100 watt HiWatt (my favorite brand!) amplifier and let it crank, but the neighbors probably wouldn't share your enthusiasm! The PGA1 was designed to give you hours of enjoyment playing your favorite electric guitar while isolating your family, friends, and neighbors from your music and your passion. (I still use the original engineering prototype with my SG with P90's!)

Whether you use an electric, acoustic electric, or bass guitar, the PGA1 gives you an adjustable volume output to your favorite headphones. Unlike a lot of practice amps, the PGA1 has a special bass boost to enhance bass guitar use. One practice amp for all your guitars! If you want to practice to your favorite music, the PGA1 has a standard style audio input to play to your favorite music! Just plug in your Walkman style CD player, MP3 player, or even the headphone output on your mixer board and you'll hear both your music source and your guitar in your headphones!

The PGA1 uses a powerful LM386 power amplifier to provide one watt of power to your headphones, or even a small speaker! It gets even better...use the PGA1 as a cheap and easy direct inserter box to match your guitar into an aux input of a stereo receiver amplifier or PA amplifier! It sounds GREAT! A standard 1/4" audio input connector is used for your guitar input, matching your standard guitar cables. A top mounted on/off/volume control adjusts the headphone output level through the full range. The small belt clip pocket size device runs on a standard 9V battery (not included). A LED indicates power-on and relative battery condition. The attractive compact case measures 4.5"H x 2.7"W x 1.1"D.

Available in a kit form to "learn as you build" or factory assembled and tested to get playing right out of the box!

PGA1 Personal Practice Guitar Amp Kit **\$64.95**
PGA1WT PGA1 Factory Asmb & Tested **\$99.95**

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- ✓ A lot of our kits are also available "factory assembled and tested", if you don't want to build them!
- ✓ We have over 350 products currently available, and all those don't fit here!

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GETTING STARTED WITH PICs

THE LATEST IN PROGRAMMING MICROCONTROLLERS

■ BY CHUCK HELLEBUYCK

C LANGUAGE INTRODUCTION

IN MY APRIL COLUMN, I DID A SPEED-TEST comparison of various PIC® microcontrollers (MCUs) that were programmable in Basic, and then compared a Basic and C compiler. I made a mistake that affected the results. I claimed that microEngineering Labs' PICBasic Pro compiler outperformed HI-TECH's PICC-Lite compiler for speed, and I was wrong. PICC-Lite compiled code runs faster. I'll explain how I goofed a little later.

The response to the speed-test article was amazing. I got more emails from that article than any article prior. Several knowledgeable C language people pointed out my mistake. I also had a few people point out that Revolution Education's PICAXE programming system could be "overclocked," meaning it could be run with an 8 MHz or 16 MHz resonator in place of the 4 MHz resonator I used in the speed test. At 16 MHz, the PICAXE would run almost as fast as Basic Micro's Basic Atom.

This was great feedback, since it indicates that readers of this column include programmers from various experience levels and are reading the details. In other words, they aren't falling asleep reading my stuff. Now let me explain the error.

CODE ERROR EXPLAINED

If you missed the April column speed test, I just did a simple For-Next loop that continued for 255 iterations, and within the loop I processed a

simple math equation to increment a variable. I toggled a pin outside the loop so I could measure the processing time on an oscilloscope, as shown in Figure 1. In the article, I made one mistake that several C programmers pointed out. In the section where I compared PICBasic Pro to the PICC-Lite compiler, I declared two "int" variables in the C compiler version of the speed-test code.

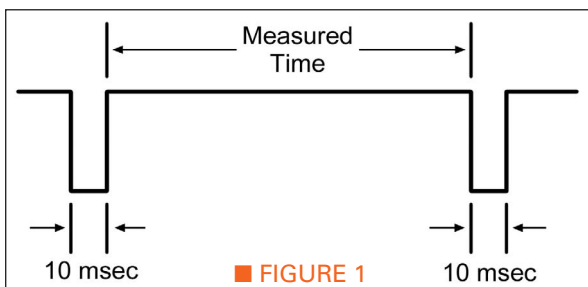
This was a huge mistake in a speed test program, since "int" creates a 16 bit variable in the C program — but in all the Basic versions of the code I declared byte variables. This greatly affected the speed results. You see, the PIC MCUs I used in the article were eight bit microcontrollers, meaning they have an eight bit wide data bus. To process a 16 bit variable, the program has to perform the math function in two steps: low byte then high byte. This takes twice as long. Therefore, it incorrectly showed the C compiler slower than PICBasic Pro.

To add to the confusion, I didn't even realize until much later that I also sent the final version of the article with a typo in the C code embedded in the text. The C code in the published column included the For-Loop variable changing from 0 to less than 256; when in reality I ran it 0 to less than 255 because I knew a byte variable would always be less than 256.

Changing from 256 to 255 should have tipped me off to the "int" variable error, but I completely missed it. You see, a byte variable will roll over to 0 after reaching 255 — since the 256 decimal is 100000000 binary. As this shows, it takes nine bits to store the 256 decimal and the lower eight bits (or byte) are zeros. So, I was thinking byte variable in my corrected code, but left the 16 bit "int" variable declaration in the code. If I wasn't focusing on a speed test, it wouldn't have been an issue.

I even admitted I was shocked by the results of the PICBasic Pro compiler being faster than C. I tested it on another processor, but got the same results since I made the same mistake. If an operating system supplier finds a bug, then they release an upgrade. This article is my upgrade! I'm correcting my mistake and clearly pointing out that the speed of the PICBasic Pro was fast, but not as fast as the corrected version of the C code compiled by the PICC-Lite compiler.

After a very nicely written email from Langue Rodriguez pointed out my mistake, I went back and declared the variable in the C program as an unsigned "char" variable (which made it an eight bit variable) and re-ran the speed test. The corrected code is shown in Listing 1. This re-test showed the PICC-Lite C program was faster than PICBasic Pro by 460 microseconds, with the setup running at 4 MHz. The PICBasic Pro program took



■ FIGURE 1

1.76 milliseconds and the corrected HI-TECH PICC-Lite version only took 1.3 milliseconds.

This was a good lesson for me to have extra eyes review my code before releasing articles in the future, and I promise to do that. It also taught me something I never really thought of prior to this. Declaring the correct size variables can have a huge impact on the processing time of your code.

I remember many times when I wanted to create a variable that would contain values only slightly larger than 255. I would declare a 16 bit value or a word variable in PICBasic Pro. Now I see how this cost me significant processing time. To understand exactly how much it cost me, I re-ran the PICBasic Pro code with a 16 bit “word” variable declared. It was a lot slower than the C program with the “int” variable. PICBasic Pro took 2.6 milliseconds with a 20 MHz resonator and 13.1 milliseconds with a 4 MHz resonator. The PICC-Lite compiler took 720 microseconds at 20 MHz and 3.6 milliseconds at 4 MHz. It’s very clear by looking at this the PICC-Lite compiler handles 16 bit math much more efficiently than the PICBasic Pro.

All this speed comparing between these two fine compilers is relative, though, because — despite this 16 bit variable slowdown — PICBasic Pro with a 16 bit variable declared and running at 4 MHz was still faster than the PICBasic standard version — even with the variable still set as a byte (reference Table 1 from April). I’m often asked, “Why should someone spend a couple of hundred dollars for the PICBasic Pro compiler when they can program with a cheaper option?” This is clearly one of the reasons.

In many projects, high speeds won’t matter. But in cases where it does, it’s good to know the limits — especially if your program has lots of math equations. Those applications may be the time where you use a byte variable for the low byte, and then have a second byte variable for the high byte, followed by a check to see whether the low byte overflowed before updating

the high byte. This would save processing time, since you are working with byte-sized variables.

OTHER COMPILER CHOICES

Another batch of comments came from people curious about other compilers, such as Crownhill Associates’ Proton Basic compiler. I’ve tried it in the past and remember it using a slightly different setup than Parallax’s BASIC Stamp PBASIC style, which the test program was based on. I decided to try

Proton on this speed-test code. I downloaded the sample version of Proton to see if it supported the same chips I used. The sample version doesn’t support the PIC16F876A or PIC16F877A, but did support the PIC16F877. I dug around and found one of those older chips, so I was able to run it. I was pleasantly surprised to find the same speedtest.bas program compiled in Proton, but I got a few warnings.

Proton prefers you to use the DIM instead of VAR directive for creating variables, and it uses a different command than PAUSE for delays. The compiler did compile it, though, and

LISTING 1

```
#include <pic.h> // Include HITECH CC header file

void Pause( unsigned int usvalue ); //Establish pause routine function
void msecbase( void ); //Establish millisecond base function

main()
{
    PORTB = 0; //Clear PortC port
    TRISB = 0; //All PortC I/O outputs

    while(1) //loop forever
    {
        unsigned int z, y;
        RB0 = 1; // Turn on RC0 LED
        for(z=0; z<255; z=z+1)
            y=y+1;

        RB0 = 0; // Turn off RC0 LED
        Pause(10); // Pause 10 msec
    } //End while
} //end main

/*****
//pause - multiple millisecond delay routine
*****/

void Pause( unsigned int usvalue )
{
    unsigned char x;

    for (x=0; x<usvalue; x++) // Delay usvalue in milliseconds
        msecbase(); // Millisec delay routine
}

/*****
//msecbase - 1 msec pause routine
*****/

void msecbase(void)
{
    OPTION = 0b00000001; //Set prescaler to TMRO 1:4
    TMRO = 0xd; //Preset TMRO to overflow on 250 counts
    while(!TOIF); //Stay until TMRO overflow flag equals 1
    TOIF = 0; //Clear the TMRO overflow flag
}
```


just gave warnings. The warnings even stated the commands were recognized for backward compatibility, which is a nice feature. I only ran the test at 20 MHz on the PIC16F877. As it turned out, my test showed Proton ran exactly equal to PICBasic Pro, completing the loop in 350 microseconds @ 20 MHz.

Lange also sent me an email that he had tested a corrected version of the C file on the CCS C compiler, and included the results in his email. He reported a result of 1.794 ms at 4 MHz with the variable corrected to eight bits (int8). According to this result, CCS is slower than PICBasic Pro's 1.76 ms in eight bit mode, but I really wanted to confirm this, so I ran it myself.

I measured 1.792 ms when I tested Lange's code with the CCS PCM version and a PIC16F877A at 4 MHz. To get this accuracy, I used a much finer resolution on the scope. I went back and re-measured the PICBasic Pro code at this scope resolution, and found it to be 1.790 ms. Therefore, I concluded that the CCS and PICBasic Pro compilers ran at the same speed, and that my previous measurement had some resolution error. I ran the PICC-Lite at this finer resolution, but

got the same 1.300 ms result as before. Lange's CCS code is shown in Listing 2 if you want to test it yourself.

C INTRODUCED

This seems like a good point to introduce some simple C coding to those who haven't worked with this language. The C language at first seems a lot different than Basic, but in reality, it's more format than anything. C code for PIC MCUs is different than trying to write C code for a PC application. In this respect, having the PIC MCU experience from programming in any other language is a bonus, because you understand the internal setup. For example, let's take the very simple program in Listing 3 written for the HI-TECH PICC-Lite compiler. (It just lights an LED on PORTB bit 0.) I use it because it shows the basic structure of C coding. The top of the file has the line

```
#INCLUDE <pic.h>
```

This includes all the necessary PICC-Lite compiler setup information in the program, and each C compiler will have its own version of this included file.

The next line establishes the configuration settings. I wrote this simple program in Microchip's MPLAB® integrated development environment (IDE) and

set it up as a project. In the project setup, I selected the PIC16F876A. The #if to #endif block of code tests for this processor selection, and if any of those listed are selected in the MPLAB IDE, the compiler will include the configuration fuses to run in the external crystal mode (XT) with watchdog timer (WDT-DIS), brownout reset (BORDIS), and low voltage programming (LVPDIS) disabled. This will get transferred to the programmer automatically, through the final compiled and assembled .hex file.

The main body of the code is next. All C programs begin execution in a function named "main()", which may be passed any arguments from an external source. Every function in C is bounded by a set of braces, and main() is no exception. The first thing we do in main() is to set up the PORTB and TRISB registers. We clear them both to make all of the PortB pins set to outputs and cleared. This doesn't look much different than a Basic program.

The program then executes a continuous loop with the while() statement. The expression in the parenthesis is evaluated and, as long as it is true (a logical 1), the commands within the while statement's set of braces are executed. This is also not much different than the While command in many Basic compilers, except the commands are not contained within parenthesis. In this case, the formula is simply "1",

LISTING 2

```
*****
```

c-file follows:

```
// Basic program to compare speed and code size
#include <16F876A.H>
#define *16
#fuses XT, NOWDT, NOPROTECT, BROWNOUT, PUT, NOLVP
#use delay(clock=4000000)
```

```
#define RB0 PIN_B0
```

```
//=====
```

```
void main()
{
    int8 z, y;
    while (true)
    {
        output_high(RB0);
        for (z=0;z<255;z++)
        {
            y++;
        }
        output_low(RB0);
        delay_ms(10);
    }
}
```

```
*****
```

LISTING 3

```
#include <pic.h> // Include HITECH CC header file
```

```
#if defined(_16F873A) || defined(_16F874A) || \
    defined(_16F876A) || defined(_16F877A)
    _CONFIG (XT & WDTDIS & BORDIS & LVPDIS);
//XT Crystal Mode, Watchdog off, BrownOut Disabled
#endif
```

```
main()
{
    PORTB = 0; //Clear PortC port
    TRISB = 0; //All PortC I/O outputs

    while(1) //loop forever
    {
        RB0 = 1; // Turn on RC0 LED
    } //End while
} //end main
```

```
end;
```

which is a wonderfully useful expression mechanism in C — just about everything can be used as a boolean value (those things zero are FALSE, those non-zero are TRUE). Since the while() loop conditional will always return TRUE, it will loop forever. The commands within while() sets RB0 or PortB bit 0 to a one, which turns on the LED.

The program is completed by putting the closing braces for both the main() function and while() loop. It closes with an end command.

One thing to note with the structure of C is that all command lines — AKA statements — end with a semi-colon. This is one of the biggest errors for beginners, as it is not required in assembly or Basic. Also, comment lines start with a double backslash — not a colon or semi-colon like assembly or Basic. If you can get past the braces and colons, the program doesn't look much different than a PICBasic program. You can see some of the differences between the HI-TECH PICC-Lite and the CCS C compilers by comparing Listing 3 to Listing 2. I mainly wanted to introduce the basics of C code, and plan to help you learn more as this column progresses along.

CONCLUSION

I still feel that programming PIC MCUs in Basic is the best option for the beginner, but if you want to do any programming outside of the hobbyist arena, you should at least learn some C. I started with assembly and have used Basic for years, so those are like second nature to me. Adding C to my software skills made programming PIC MCUs even more fun, and I hope to pass on what I know to those that want to learn C, as well.

I've watched and helped many complete beginners get started

programming by using the Basic Atom and PICBasic Pro. I also know others who learned with the various other options. There is no single correct choice. If Proton or PICC-Lite or PICAXE or BASIC Stamp or any other choice gets you started programming PIC MCUs, then go for it. When I started, the choices for the hobbyist or beginner were limited and finding help was next to impossible.

I often wished that I had someone

teaching me or had books to read when I got started, but I couldn't find many. Those books I did find were written for the professional and were often way over my head. I had to find all this out on my own. I hope you keep reading, and I'll be more careful about the errors. Send me emails with your feedback, because as you can see, I listen. Send them to chuck@elproducts.com and stop by my website anytime at www.elproducts.com. **NV**

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WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

- ✓ Variable Timer.
- ✓ Solar Cells.
- ✓ PCB Layout Programs.

WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions.

Send all questions and comments to:

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VARIABLE TIMER

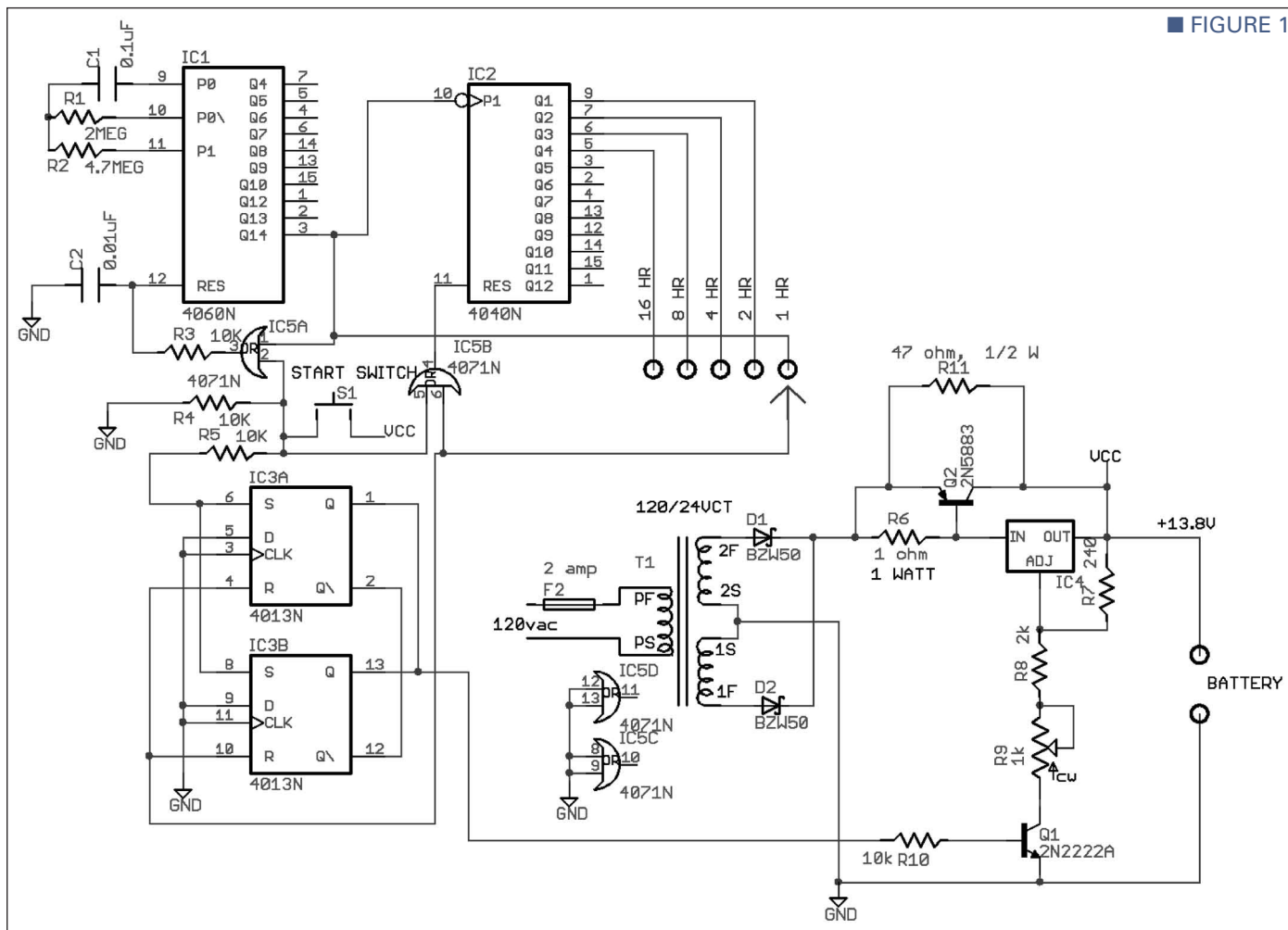
Q I need a timer to charge small rechargeable batteries. I need outputs of 1, 2, 4, 8, and 16 hours. I have a 1, Pole 5, throw switch for time

selection. I can do all the peripheral work such as relays and LEDS, etc. I just need the outputs. I already have the power supply and transistors for charging and discharging the outputs at about one amp. I have 4060s, 4040s, 555s, other ICs, and

the resistors and capacitors.

— William D. McMurray

A I don't know why you want a timer because a battery can be left permanently connected to a good charger



without a problem. But, since I don't know your application, here is my solution:

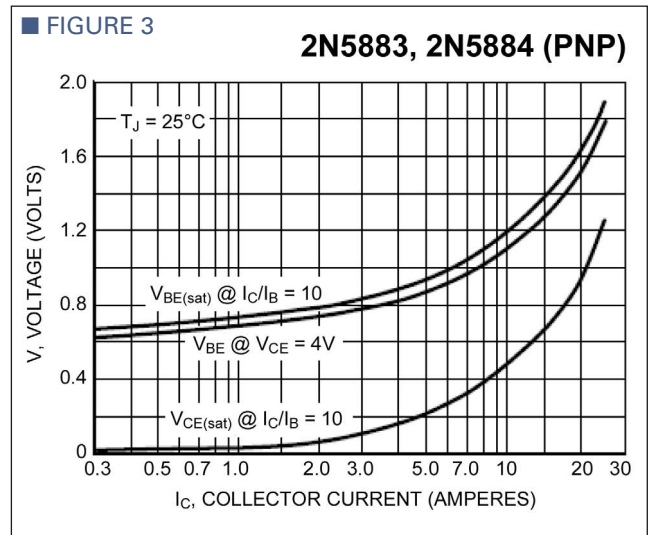
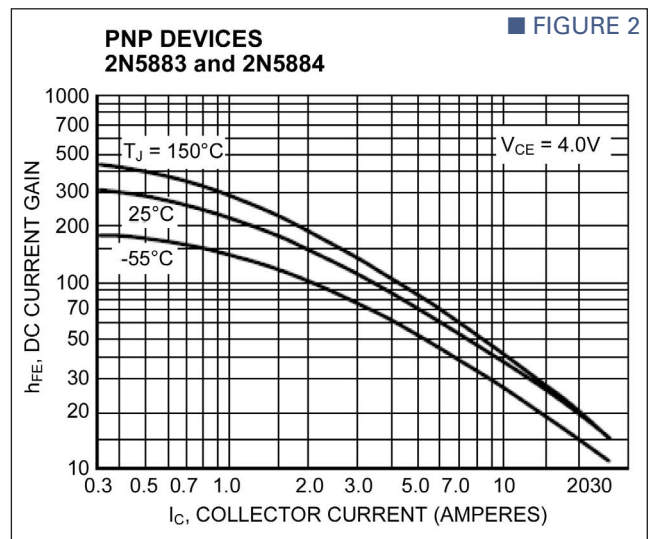
I can see you put some thought into this. Having the times in binary increments makes it easy to use a binary counter. The 4060 has a built-in oscillator and we want an output in one hour (3,600 seconds). The 14th stage of the 4060 divides by $2^{14} = 16384$. If we divide $3600/16384 = .2197$, that is the input period needed to give a one hour output period. But there is a problem: The output starts at zero; after a half hour, the output goes high and stays high for a half hour. I want to feed the output back to the reset pin — which is active high — in order for the counter to cycle every hour. So, I need to double the input period to .439. The data sheet gives the equation for period as: $T = 2.2 \cdot R_x \cdot C_x$. Choose $R_x = 1$ megohm, then $C_x = .439/2.2 \mu F = .2 \mu F$. Since $0.2 \mu F$ is hard to find, use $0.1 \mu F$, then $R_x = 2$ megohms. The resistor, R_s , just has to be large; use 4.7 meg. See the schematic in Figure 1.

In the feedback loop, I used a 10K and .01 μF cap to provide some delay; otherwise, the reset pulse will be so narrow that you can hardly see it on a 100 MHz scope.

I chose a 4013 set-up as a set-reset flip-flop to start and stop the charge. The two flip-flops in the 4013 are connected in parallel in order to give more output drive. A momentary push button is used to start the charge; the five position switch selects the time to reset the flip-flop and stop the charge. The reset pulse is fed to a 4040 counter to produce the longer times. The first output (Q1) will be two hours; the next output (Q2) will be four hours, etc. I had to introduce some OR gates in order to reset the counters at the same time that the start flip-flop is set.

The charging circuit uses an LM317T. It has a current limit of 1.5 amps; if that is enough current, you can eliminate Q2 and R6. The 2N5883 is rated 25 amps maximum but cannot supply that much current in this circuit. Here is why: It takes

one-half amp through R6 to start turning Q2 on; that leaves one amp base current for Q2 when the LM317T is at current limit. Referring to Figure 2, h_{fe} versus collector current, note that the gain is down to 20 at 20 amps, so with only one amp base current available, that would be the maximum current output. But the base-emitter voltage increases with base current, further reducing the possible output. Referring to Figure 3, the line labeled $V_{be@V_{ce}=4V}$ is pertinent. Note that V_{be} at 20 amps collector current is 1.6 volts. With one ohm and 1.5 amps, we can't get there, so 20 amps output is not possible. Let's see if we can get 10 amps. At 10 amps, the gain from Figure



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2 is 40. V_{be} , from Figure 3, is 1.1 volts, leaving 0.4 amps for base current. $40 \times 0.4 = 16$ amps, so 10 amps at least is possible.

I put a 47 ohm, one watt resistor across Q2 to provide a trickle charge to the battery when the charger is off. When the battery is fully charged (about 14 volts), the peak voltage across R10 will be four volts, giving a peak trickle current of 85 mA.

The size of the fuse in the transformer primary can be determined as follows: The transformer ratio is 10:1 so, the primary current is one amp when the load is 10 amps. Use a two amp fuse so it only blows under conditions of transformer or regulator failure.

SOLAR CELLS

Q I am a novice when it comes to solar cells. I recently bought six cells and started playing with them. I noticed that even though they are all from the

same company and the same make, they produce different outputs. Is this normal? Also, when I paralleled two cells, if I did not put a diode in series with each, I would get a lower value than the average cell voltage. I was not expecting these results.

Could you please shed some light on this? Do you always need to use a diode in parallel with each cell when trying to build up the amperage? I guess it goes without saying that you only need one diode in series with two cells in series for greater voltages.

Background: If you test the cells by themselves (open circuit), four of these solar cells are producing 15 to 17 VDC, with two only producing eight volts. The short circuit current is 100 to 140 mA.

Also, could you explain how to choose a solar cell for a project? I understand if I am running four 12 volt fans at 100 mA, I would add up the total amps: 400 mA for the project. But from what I am seeing on my meter, my voltage drop is a lot lower

than what I would expect for a parallel circuit. Do I need to add a capacitor or something?

— DW

A Most solar cells are made from silicon and have an output voltage of 0.5 volts. What you have is a series array of about 30 cells, giving an output of nominal 15 volts. There are several ways to make a solar cell, but they all act like diodes. You can connect them in parallel and the output will be that of the highest cell. I don't know what is causing the effects that you see. Perhaps you bought some production rejects. You should not need a diode between units; the units themselves are a diode. The power output of the solar array must meet or exceed the power required by the load. If you need 400 mA at 12 volts (4.8 watts), the solar array must exceed that because the sun is not at maximum most of the time. You can get good information from this URL: www.solarserver.de/wissen/photovoltaik-e.html#from.

(The July issue of Nuts & Volts will have extra "green power" coverage, so stay tuned!)

PCB LAYOUT PROGRAM

Q I would like to download a PCB artwork program. Do you know of any?

— Anonymous

A I assume you mean a free PCB layout program. A Google search turned up these possibilities: www.ExpressPCB.com, www.PCB123.com, www.freePCB.com, and www.cadsoft.de. The first two are produced by companies that hope you will use their facility to make the PC boards. My reading of reviews indicates that these are full featured. FreePCB is open source freeware and the one review I saw indicated that it was good. I included Cadsoft because I am using their Eagle program. The free version is limited in board size and parts count but should be adequate for your use. There is a good manual and online help is excellent. **NV**

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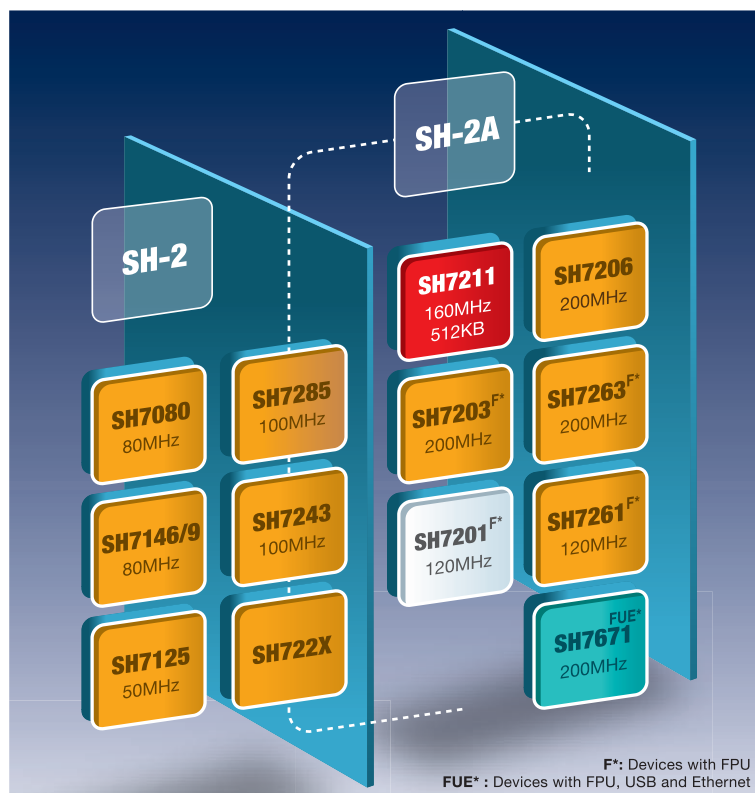
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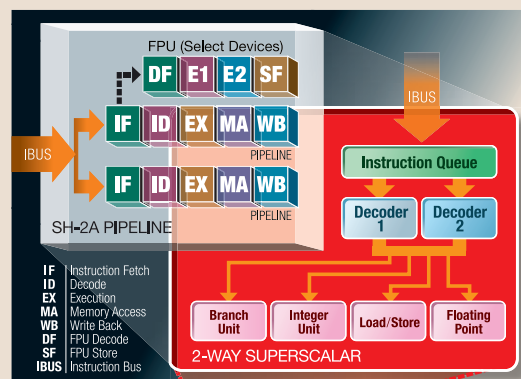
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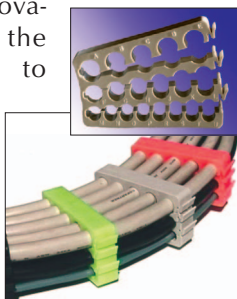
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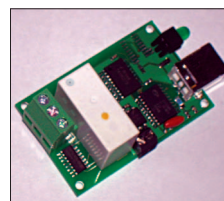


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replaces internal PC-based plug-in cards in various test, control, monitor, and measurement applications. Complete product specifications are available at the J-Works website. Single unit price for the Model JSB370 starts at \$75. Delivery is from stock.

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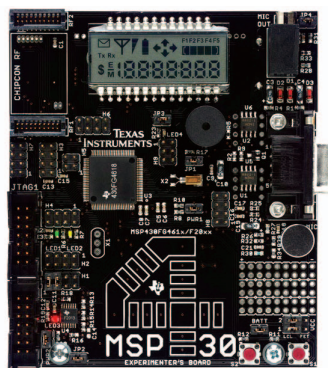
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chip (SCoC) MSP430FG4618 or small 14-pin F2013 microcontroller, Texas Instruments announces the availability of the MSP430 Experimenter's Board (part number MSP EXP430FG4618). Along with the two 16-bit MSP430 devices, the board includes a TI (Chipcon) radio frequency (RF) module connector for developing low power wireless networks. The board also features a number of input and output options such as a microphone, buzzer, liquid crystal display (LCD), capacitive touch-pad, push buttons, and pin board prototyping space, among others.

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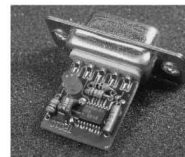
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Combined with the two devices is a host of interfaces and input/output options that allow a designer to quickly evaluate the suitability of either MSP430 MCU. JTAG headers on the board make both devices accessible for programming and debugging, as well as communication between the two MSP430s or to other external devices. A variety of input options include a microphone, capacitive touchpad, and push buttons. Output peripherals include a buzzer, LCD,

RS-232 communication interface, and 3.5 mm headphone jack for analog output.

To accelerate the development of low power wireless RF systems, the Experimenter's Board includes connectors for various Chipcon evaluation modules, which cover the <1 GHz and 2.4 GHz frequency bands (including IEEE 802.15.4/ZigBee™ standards). Supported modules are the CC11x0, CC25x0, and the CC2420 evaluation kits, which are available separately.

The MSP430 Experimenters Board is available for \$99 and requires a Flash emulation tool, such as the MSP-FET430UIF, available separately starting at \$99. Chipcon evaluation boards are available at www.ti.com/estore.

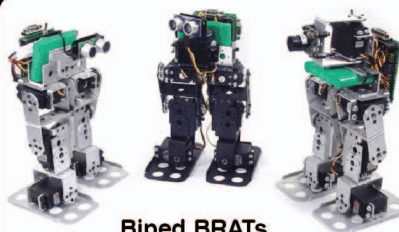
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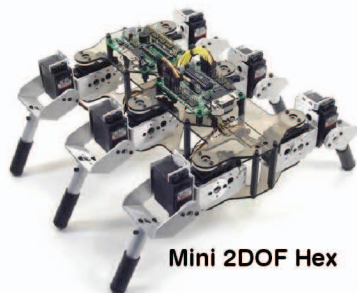
The Cropico DO4A from Clare Instruments US, Inc., is a highly versatile, digital ohmmeter used for low resistance measurement across a diverse range of production, safety, and design engineering applications.

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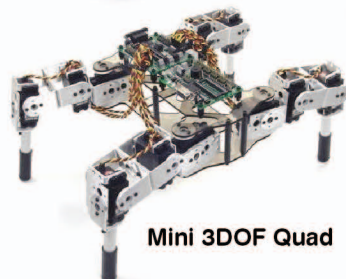
The DO4A uses True 4 Wire measurement to eliminate lead resistance errors across a push button selectable range from 40 mW to 4 kW with respec-



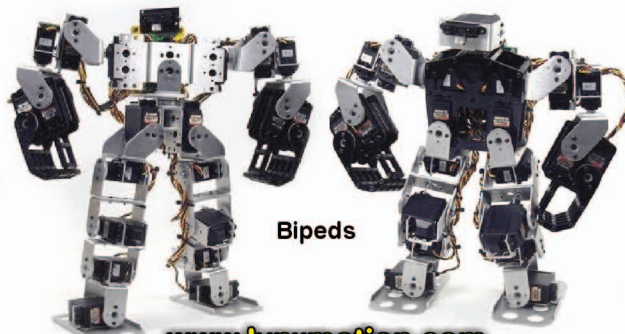
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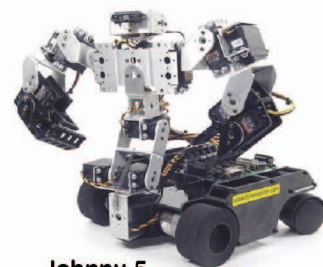
Mini 2DOF Hex



Mini 3DOF Quad



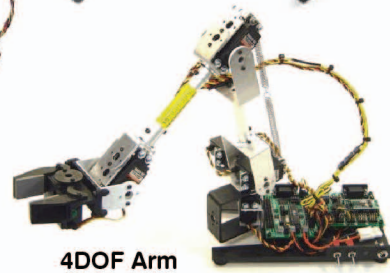
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Contained in an aluminum case with a tilted carrying handle, the robust unit is a highly practical instrument that can be used in the workshop, by field or maintenance engineers, or as part of more comprehensive electrical test facilities. Input protection is provided up to 415 volts rms.

For ease of operation, the control functions have been kept to a minimum and a four digit LCD gives direct readings of the resistance measured, with over range and low battery indicators also provided.

Other special features include an auto zero facility where thermal EMF may cause a large measuring error and warning LEDs to indicate an open circuit lead condition.

Rechargeable batteries provide full portability with over 14 hours of continuous working on the lowest ranges and 28 hours of operation on others.

The Cropico DO4A is supplied ready for immediate use and comes complete with battery, mains cord, and measuring leads. In addition, a wide range of optional accessories including duplex handspikes, other specialist clips, long length leads, and wire clamps further extend the instrument's versatility.

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THE NEW SCHMARTMODULE

SchmartBoard, the developer of a new technology that has significantly simplified the creation of electronic circuits for hobbyists, education, and industry, announces the release of a new product — the Power SchmartModule.

A few benefits to the new module include: they allow virtually anyone to hand solder; users can surface mount components easily, quickly, and flawlessly; and dexterity to hand

solder surface mount components with small pitches is not required.

Additionally, SchmartModules offer pre-designed common circuits that allow designers to quickly and easily add common functionality without having to "re-invent the wheel."

The Power SchmartModule allows users to power up circuits with one of seven voltages, which include: -9, -12, +2.5, +3.3, +5, +9, and +12 volts. The product comes as a bare board with a bill of materials, schematic, and simple

instructions. Users solder the components onto the board themselves. The board uses SchmartBoard's patent-pending "ez" technology to make soldering fast and easy. Because the product has variable power options, one can reuse the product on many different circuits if they choose. The suggested retail price of the board is \$15.

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■ THIS MONTH'S PROJECTS

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■ LEVEL RATING SYSTEM

To find out the level of difficulty for each of these projects, turn to our ratings for the answers.

- Beginner Level
- Intermediate Level
- Advanced Level
- Professional Level

In the first couple of installments of this series, we used a PC to take measurements and display the results from our 1-Wire sensors. The major drawback for building a PC-based weather station is that the PC has to be on all the time. While the programs can run in the background, you do tie up any serial port you have connected to your PC. In this article,

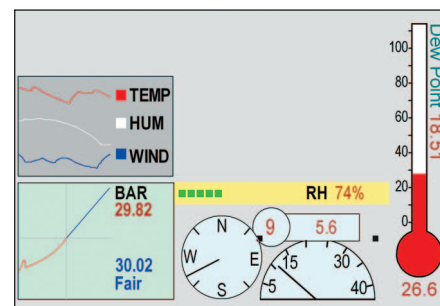
I am going to show you how to build a complete microcontroller-based weather station complete with color display.

CONTROL YOUR WORLD WITH AN X-10 INTERFACE

Microcontroller-Based Weather Station

Let's take a look at some of the benefits of a microcontroller-based weather station:

- Multiple 1-Wire networks for reliability.
- Full color display.
- Does not tie up the PC.
- Calculates Dew Point, Wind Chill, and Heat Index.
- Displays one minute wind speed average, as well as gusts.
- Displays real-time wind direction updated several times a second.
- Real-time status indicator for each sensor.
- Plots last 24 hour readings for temperature, humidity, and wind speed.



- Tracks and plots last 24 hour barometer readings.
- Displays 12 hour barometer forecast.
- Large portion of the display area is available for other sensors such as lighting, or moisture gauges.

Display System

For our display system, we will be using the ezLCD001 from Earth Computer Technologies, Inc.; www.EarthLCD.com (Figure 1).

The ezLCD001 has a 240x160 TFT color display. It has a built-in, software controlled backlight and several interface options:

- RS-232 level serial interface
- TTL level serial interface
- USB interface
- I²C interface
- SPI interface
- Eight-bit parallel interface



■ FIGURE 1

In this article,

we are going to be using the I²C interface with our weather station. To power the display, anything from 3V to 6.6V will work. I am going to use a DiosPro microcontroller because of its low cost and the fact that it already has a complete set of built-in ezLCD001 and 1-Wire libraries. We will be using the DiosWorkboard Basic as the carrier for both the DiosPro and ezLCD001.

Initial Construction

We need to add a couple of headers so that we can plug the ezLCD001 into the Workboard. Schematic 1 shows the display hookup. Note that we have connected the display to ports 10, 11, and 12. You may use other ports as well, but keep in mind you will need to change the ezLCDinitI2c parameters if you do.

Before you continue, you need to think about how you are going to mount the Workboard and the external modules/connectors. I mounted mine to a 5" x 7" piece of compressed PVC. I used a narrow RJ11 jack for my outdoor network, as shown in Figure 2. This can be attached by screws or double-stick foam tape.

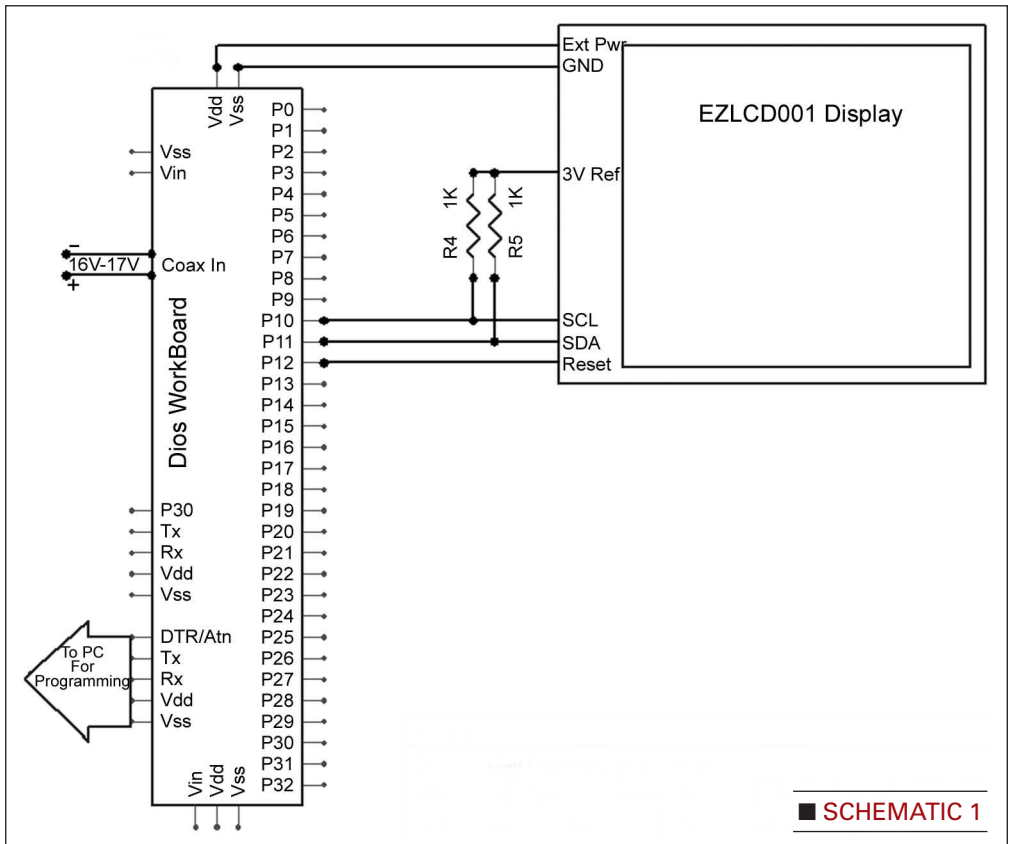
The Workboard is attached using 1/4" standoffs but could have been attached without them.

STEP 1: Build the Dios Workboard Basic as per the instructions included with the kit available from Kronos Robotics (see Web Links). The only modification that you need to make is to add a TO-220 heatsink to the onboard 5V regulator. This is done by gently bending the regulator so that it is standing up. Once this is done, you can slip the heatsink over the regulator as shown at the top of Figure 3.

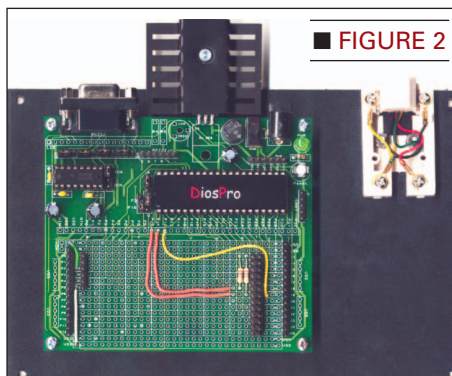
Why do we need a heatsink anyway? We need to supply 14V to

the Hobby Boards barometer. In order to do this, we need to supply at least 16V to the DiosPro coax. This will yield approximately 14V to the input of the 5V regulator. With the added load of the display, as well as the outdoor 1-Wire network, the onboard regulator starts to get warm. The heatsink will keep the temperatures within the operating range.

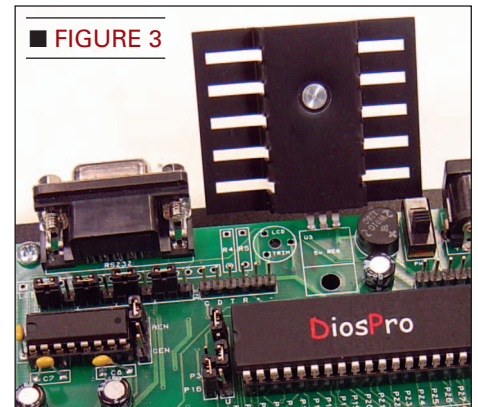
After building the board, plug in the DiosPro and test the board as per the included instructions.



■ SCHEMATIC 1



■ FIGURE 2



■ FIGURE 3

STEP 2: To mount the LCD, we need to add a couple of headers and run a few wires.

Take a six-pin header and attach it to the pads marked RC2-RH2, as shown in Figure 4.

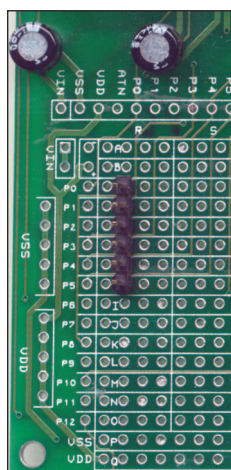
Next, take a 13-pin header and attach it to the pads marked XC4-XO4, as shown in Figure 5.

Now, take a *second* 13-pin header and attach it to the pads marked YC1-YO1, as shown in Figure 5.

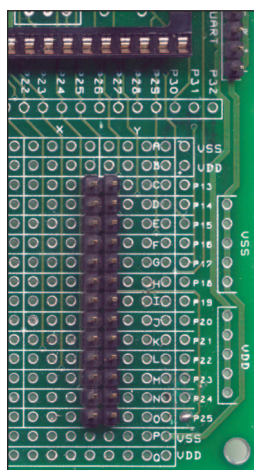
port 12. This is the reset port on the ezLCD001. The software will bring this port low each time the software starts in order to reset the display.

Connect a 14-pin header to the port pads, as shown in Figure 9. Note this is the header on the left side of the board. The header will give you access to I/O ports 0-12, as well as Vss.

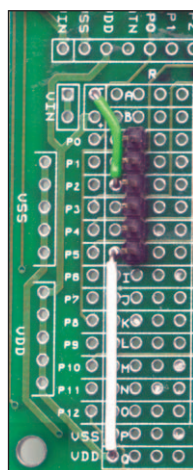
Connect a 15-pin header to the port pads, as shown in Figure 9. This is the header on the right side of the board and gives you access to I/O ports 13-25, as well as Vss and Vdd.



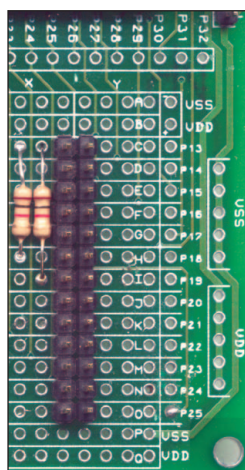
■ FIGURE 4



■ FIGURE 5



■ FIGURE 6



■ FIGURE 7

Program 1

```
'EZLCD001 Test Program
func main()

'Setup ezLCD
ezLCDinitI2c(11,10,12)    'Pass sda,scl and reset port
ezLCDLIGHTON()
ezLCDCLS (ezWHITE)

ezLCDFONT(3) 'Large Font
ezLCDPRINTXY(30,10,"Hello World",ezBLUE)

endfunc

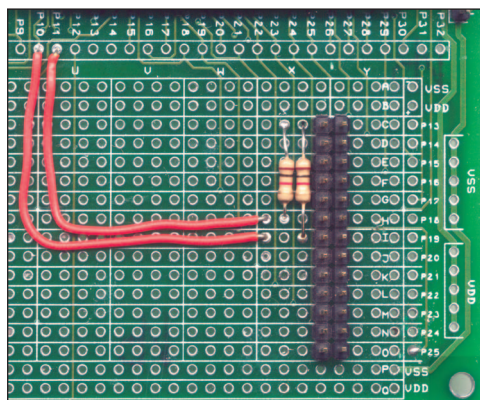
include \lib\EZLCDI2c.lib    'ezLCD001 Library
```

STEP 3: Take a small jumper and connect the pad marked RE1 and attach it to the pad marked, as shown in Figure 6. Note this is the small green jumper.

Attach a jumper between RH1 and one of the VDD pads, as shown in Figure 5. This is the white wire.

STEP 4: Attach two 1K resistors to the

■ FIGURE 8

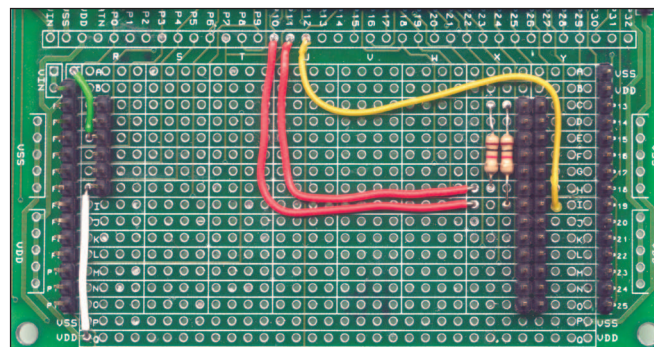


by the display itself.

STEP 5: Connect the ezLCD001 I²C SDA port to Dios port 11. The pad marked XH1 is the I²C SDA port. Solder in place, as shown in Figure 8.

Now connect the ezLCD001 I²C SCL port to Dios port 10. The pad marked XI1 is the I²C SCL port, as shown in Figure 8.

STEP 6: Connect a wire from YI2 to



■ FIGURE 9

STEP 7: Let's perform a simple display test.

Without the ezLCD display plugged into the Workboard, apply power to the DiosWorkboard via the coax connector. This should be between 15V and 17V. If you are not going to use the Hobby Boards barometer module, you may use anything within the range of 7-16V.

Load Program 1 into the DiosPro. The file called LCDtest.txt is included in the download files.

Power down the Workboard and plug the display into the six-pin and 13-pin connectors and apply power to the DiosWorkboard. The words "Hello World" should print onto the display in blue. If it does not, go back and check all your connections very carefully.

Network Connector Construction

For detailed information on 1-Wire and connection techniques, check out the March installment of the series called "Environmental Sensors." We will be running two 1-Wire networks off of the DiosPro.

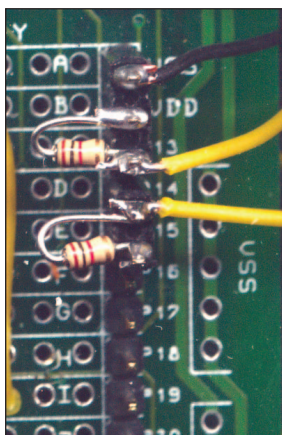
Let's start by adding a connection to a modular jack so that you can easily connect your outdoor sensors to the weather station.



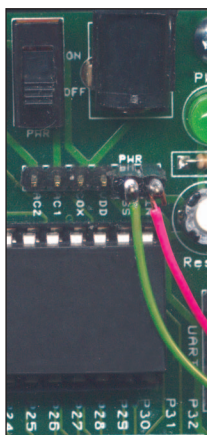
STEP 5: Snap off a two-pin section

Attach the black wire (connected to VSS) to the green wire on the connector. Attach the yellow wire (connected to P13) to the red wire on the connector, as shown in Figure 12.

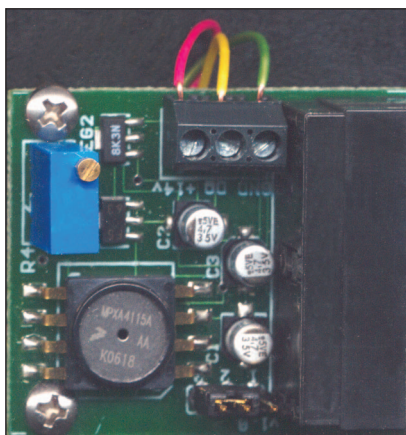




■ FIGURE 13



■ FIGURE 14



■ FIGURE 15

from a female header and slip it over the PWR header pins marked VIN and VSS. Next attach a 5" red wire to the VIN lead and a 5" green wire to the VSS lead, as shown in Figure 14.

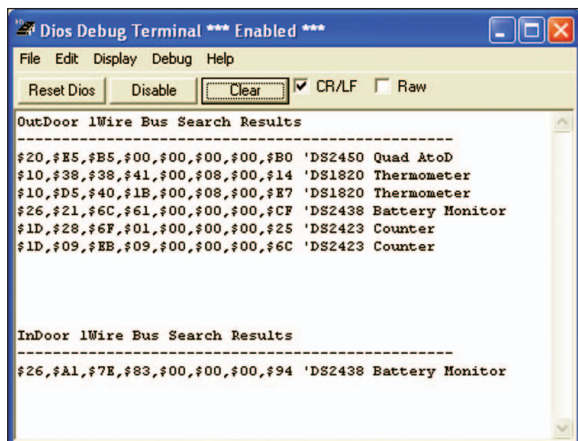
STEP 6: Attach the Hobby Boards barometer to your project base. Next attach the three red, yellow, and green wires to the board, as shown in Figure 15.

STEP 7: With construction complete, you need to remove the ezLCD display if it is attached and power-up the Workboard.

Load the file named Networktest.txt that is included in the download files and program it into the DiosPro. The program will display the status of the two networks.

When you plug your outdoor network into the modular jack, it should report a good network.

■ FIGURE 16



Weather Station Software

Okay, all the hard work is done. The hardware construction is complete and tested. Now comes the most rewarding portion of the project.

I am going to take you through adding the code for each sensor one at a time so that you can customize the software for your configuration. As we add each software component, you will see your weather station come to life.

The ezLCD display screen was difficult to photograph because the glass bezel on the display added a moiré pattern. In order to show you what the different gauges should look like, I created some drawings that actually came very close to the actual display.

You will need the registration numbers from all the devices on your network so that you can paste them into the appropriate routines. If you don't already have these numbers, load and run the DiosPro file called Networksearch.txt. This program will display the registration numbers on each of the networks in the debug window, as shown in Figure 16.

Outside Temperature Sensor

Load up the file called LCDweather1.txt. Take a

look at the file and you will notice three sections in the program. Each of the programs that we are going to load have these three sections.

- *Basic Setup* — This is where the 1-Wire ports are defined, the timers are started, and the LCD is initialized. This part is the same for each of the programs we are going to load in this section.

- *Draw Gauges* — Each of the gauges has to be drawn before they can be used. This is where we make a call to the function that handles the particular sensor we are adding to the weather station. In the case of the Outside Temperature Sensor, the function is called readthermometer. Also notice that we pass 0 as a parameter. This tells the function that we simply want to initialize and draw the gauge.

- *Main Processing Loop* — Here we make the same call to the processing function with a parameter of 1, which tells the function to take a reading and display the results.

Include Files

At the end of the program, there are a series of include files. These files contain functions that make up the weather station. The first include file is called LCDtmp.lib. This points to the file that actually contains all the routines that take the temperature readings and display the results. We will adding additional LCD include files as our weather station progresses.

The second include file contains the functions that set up the timers we need for our weather station. There are six timers that we used for this weather station. The timers run in the background and each one increments a global variable once every 10 milliseconds. We use these timers with various modules to help us create plots and averages for the individual sensors.

The last include file is the ezLCD library.

The Dios editor has a feature that if you double click on an include file name, it will load that file into an editor form so that you can make modifications to the file. Go ahead and double click the LCDtemp.lib name. This will open up the file containing definitions for the outside thermometer functions. Looking at the LCDtemp.lib file, you will notice a table entry called AAGTempROM: This defines the device registration number. You will need to change this number to match one of the DS1820 thermometers on your outdoor network. The registration number will need to be changed in each include file to match those on your network.

Once the registration is changed, save and close the include file. Then program the LCDweather1.txt program into the DiosPro. You should see a thermometer on your display like the one shown in Figure 17.

Figure 17 actually shows three thermometers. The first is what the thermometer looks like when it displays a normal temperature. If the conditions are present to create a Wind Chill, it will be displayed as a thin cyan bar like the one shown on the second thermometer. If the conditions are present to create a Heat Index, it will be displayed as a dark red bar like the one shown in the third thermometer. Since we don't have a humidity or wind sensor module loaded yet, you won't see either of these two indicators, nor will you see the Dew Point calculation.

Wind Speed Sensor

Load up the file called LCDweather2.txt. If you look at the file, you will see that it is identical to LCDweather1.txt. The only difference is that we added a call to the readspeed function to both the Draw Gauges and Main Processing Loop sections. There is also a new include file added called LCDspeed.lib. Go ahead and open this file and edit the table entry in the readspeed function, then program the DiosPro with the file.

The wind speed gauge cluster has

three sections shown in **FIGURE 17** Figure 18. The main gauge has a small hand that points to the indicated speed. The number above this gauge is the actual speed with a .1 mph resolution. These readings are actually averaged over the last 30 seconds. The number in the small circle in the upper left hand of the display cluster is the gust indicator. If a gust is detected and the value is higher than the number that is already displayed, it will replace that number and reset an internal gust timer. The timer also gets reset if the gust is the same as the one displayed. If no new gust is received that is greater or equal to the one displayed over a five minute period, the indicator will be cleared.

Wind Direction Sensor

Load up the file called LCDweather3.txt. A new function called readspeed has been added. Edit the LCDdir.lib file and make the registration changes to the table entry. The AAG wind direction uses the DS2450 Quad A-to-D device.

The wind direction gauge shown in Figure 19 takes a reading a couple of times each second and displays the direction the wind is blowing from.

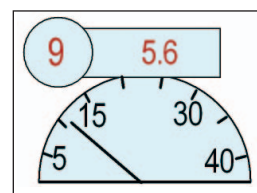
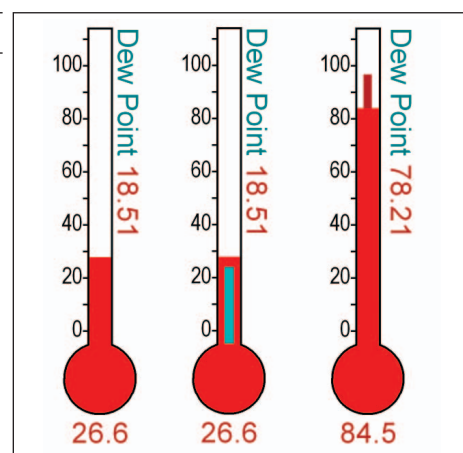
Outdoor Humidity Sensor

Load up the file called LCDweather4.txt. Here we added the function called readhumidity. The humidity sensor uses a DS2438 device.

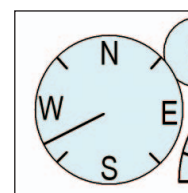
You may have noticed small green pips that were displayed near the center of the screen, as shown in Figure 20. These are sensor status indicators. When green, the sensor is working properly; red indicates they failed on the last reading. It is normal to get an occasional error.

The pips represent the following sensors:

- Pip 1 – Wind Speed
- Pip 2 – Wind Direction
- Pip 3 – Temperature
- Pip 4 – Humidity
- Pip 5 – Barometer



■ FIGURE 18



■ FIGURE 19

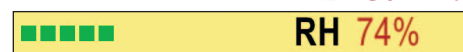
Barometric Sensor

Load up the file called LCDweather5.txt. Here we added the function called readbar. The barometer sensor uses a DS2438 device and is on the indoor network. In addition to the table entry, you need to set the slope and intercept constants, as well. These are what you used when you calibrated your barometer.

Figure 21 shows the barometer gauge. The red plot line is a history of the last 24 hours. The blue plot line is a prediction for the next 12 hours. It is based on the rate of change for the last four hours. The blue number and weather prediction is based on the 12 hour point on the plot.

The sensor is read once per minute and the red bar number is updated. The plot lines and prediction are only updated once per hour. The last 24

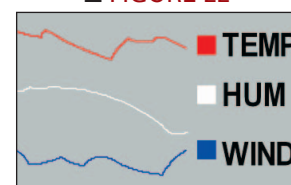
■ FIGURE 20

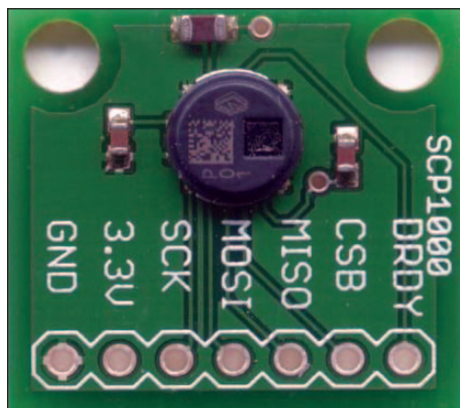


■ FIGURE 21



■ FIGURE 22





■ **FIGURE 23** Load up the file called LCDweather6.txt. Take a close look at the program. I have a new set of functions called calchistory. All the sensors that we have added use global variables to store their readings. The calchistory function takes the temperature, humidity, and average wind speed and plots them on the graph once per hour, as shown in Figure 22. This way, the last 24 hours are shown. In addition to the display, these readings are stored in the DiosPro EEPROM so that if we have to reset the chip, we won't lose the graph information.

Final Thoughts

We covered quite a bit of material in this article. I understand that many of you will want to build

a custom weather station and may not be using the exact sensors that I have used here. I will be glad to answer any of your questions to help you make your modifications. Please use our Weather Center and Home automation forum at www.kronosrobotics.com/forums/viewforum.php?f=25.

There is plenty of unused space on the ezLCD display. In the future, I will be adding a rain gauge, as well as moisture and various other sensors.

I have been experimenting with the SCP1000 available from Spark Fun Electronics shown in Figure 23. This is one accurate pressure sensor and can track barometric pressure to three decimal points. It's faster and more accurate than the 1-Wire sensors. It also has an onboard temperature sensor. This particular model uses a two-wire I²C interface and a complete Dios library is available. If you decide you want to use one of these, check out the application note on the Kronos robotics website at www.kronosrobotics.com/Projects/SCP1000.shtml.

What's Next

Next month, I am going to look at adding a couple remote Zigbee units to the sensors on our weather pole. This will make our weather station truly portable.

All the source code is available for download at www.kronosrobotics.com/Projects/weathermicro.shtml. **NV**

PARTS LIST

EarthLCD

□ ezLCD001

<http://store.earthlcd.com/LCD?sc=7&category=297>

HOBBY BOARDS

□ DS18S20 1-Wire Temperature Sensor
www.hobby-boards.com/catalog/product_info.php?cPath=26&products_id=93

□ Barometer Module (B1-R1-A) — www.hobby-boards.com/catalog/product_info.php?cPath=22&products_id=36

□ Humidity Module (H3-R1-A) — www.hobby-boards.com/catalog/product_info.php?cPath=22&products_id=46

□ AAG Weather Instrument — www.hobby-boards.com/catalog/product_info.php?cPath=22&products_id=92

SPARK FUN ELECTRONICS

□ SCP1000

www.sparkfun.com/commerce/product_info.php?products_id=8161

KRONOS ROBOTICS

□ DiosPro 40 chip

www.kronosrobotics.com/xcart/customer/product.php?productid=16168

□ DiosWorkboard Basic

www.kronosrobotics.com/xcart/customer/product.php?productid=16453

□ 14V DC Adapter

www.kronosrobotics.com/xcart/customer/product.php?productid=16500

□ 36-Pin Female Header

www.kronosrobotics.com/xcart/customer/product.php?productid=16291

□ 40-Pin Male Header

www.kronosrobotics.com/xcart/customer/product.php?productid=16290

□ TO-220 Heatsink

www.kronosrobotics.com/xcart/customer/product.php?productid=16250

□ 1K Resistors

www.kronosrobotics.com/xcart/customer/product.php?productid=16178

□ Expanded PVC 5x7

www.kronosrobotics.com/xcart/customer/product.php?productid=16432

□ Free Dios Compiler (Includes ezLCD and 1-Wire libraries) — www.kronosrobotics.com/downloads/DiosSetup.exe

OTHER

□ RJ11 Surface Mount Box — I used a GETL26101. Can be purchased from most home centers.

WEB LINKS

■ Hobby Boards
www.hobby-boards.com

■ Spark Fun Electronics
www.sparkfun.com

■ Kronos Robotics
www.kronosrobotics.com/xcart/customer/home.php

■ EarthLCD
www.EarthLCD.com

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- Microchip • Molex
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- Atmel • ST Micro

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I needed a seven-segment remote display that received its data from RS-232, and I wanted it fast.

Here's a little project that can be built in a weekend and will give you four digits of information. You can use either common anode or common cathode seven-segment displays without changing the hardware!

I also wanted to use a PIC microcontroller for it in Figure 1. You'll see what I wound up with.

THE MUX MUX LIGHT DISPLAY

How to Light a Display One Segment at a Time

Seven-segment LEDs still have some advantages over the LCD displays that are very popular now. They are self lighting, large, and easy to read (like from across the room.) They are inexpensive, don't require complicated voltage converters for fussy backlit displays and tolerate wide temperature ranges (LCDs don't work too well below freezing while LEDs are quite happy operating there.)

Many of the seven-segment designs that I've seen drive all eight of the segments (seven plus the decimal point) of a digit at the same time. The problem is that there can be quite a bit of current sourced through the common connection of the digit.

One thing I noticed in existing PIC designs were four PNP transistors tied to the anodes of a typical four digit display. This is to manage the worst case current draw. For example, the display that I use typically draws about 5 mA per segment. Multiply that by 8 and you have 40 mA of

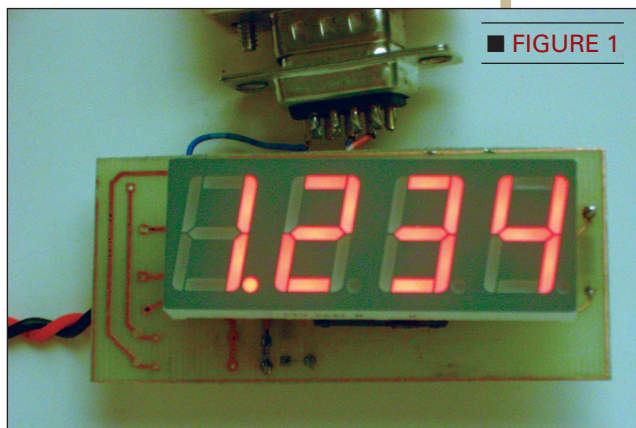
current being sourced to each digit. A PIC can only source or sink a maximum of 25 mA through any single output pin. So the PNP transistors are used as current amplifiers.

But if we only drive part of the digit at a time, we can cut down the total current requirement! I wondered if I could wire the display so the PIC sources and sinks only a single segment each pass. Would the duty cycle for each segment be too low, causing the display to be dim? I did a little bit of math and came up with the following:

$$\frac{1}{(4 \text{ digits} * 8 \text{ segments/digit}) * 60\text{Hz (a good refresh rate)}} = \text{about } 500 \text{ microseconds}$$

That's no problem for a PIC running the internal oscillator, especially since the only other thing that it's doing is reading characters from the serial input. Still, that's only about a three percent duty cycle. Would that be enough?

Let's see what we have to do. For an LED, we have a diode (light emitting diode, remember?) A diode only conducts current when the anode is positive and the cathode is negative. Further, the anode voltage



must be greater than the forward voltage of the diode (usually 1.7-2.0V). Also, there is little current flow (practically none) when the diode is reverse biased, or when the cathode is more positive than the anode.

Since I'm using a common anode display, each digit has a single connection to each of the anodes of the segment. The cathodes of each segment of the digit are connected to the cathodes of the other digit's segments. So by sourcing current in one chosen anode and sinking current in one or more cathodes (segments), a single digit can be lit on the display. By sourcing current in a different anode, another digit is lit. By doing this rather quickly, persistence of vision makes it seem that all digits in the display are lit at once.

If either the anode voltage is low and/or the cathode voltage is high, then there is no current flow, and no light from the segment. So if the circuit drives one of the anodes high, then optionally walks a zero through each one of the cathodes, we can have the display turn off and on each individual segment. If we turn on only the desired segments in rapid enough succession, then we can have the display show four unique digits at minimum current draw.

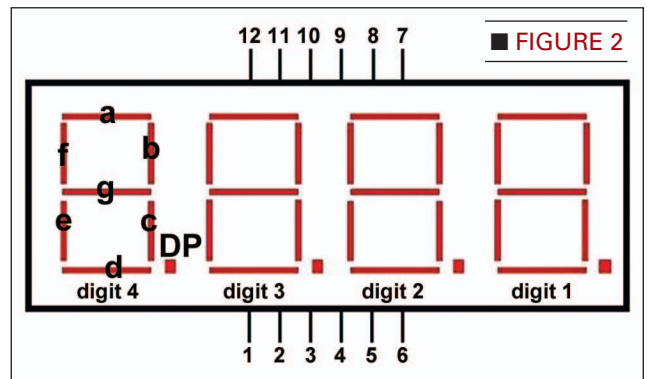
Furthermore, if we limit the current to what each PIC pin can tolerate, we

can get rid of the PNP transistors all together. We will still need a current limiting resistor though. The forward current specification of an LED is for continuous (DC) levels, but if we have a duty cycle, we can increase the amount of current through the device. Since we are trying a

3% duty cycle, we can pass close to the maximum current from a PIC output through the LED. We just have to be a little careful when debugging the code and not leave a segment stuck in the on position for too long.

So now we have the verbal description of the problem. Oh wait, there's something else (isn't there always?). I want a small form factor for the circuit without a lot of space taken up around the display itself. But I still want to use through hole design, not surface mount. It might be good to have an optional power supply on the board, too as you never know what type of power we will have around.

Now we have all of the requirements for the design. I've got a collection of four digit common anode, seven-segment displays that I bought from RSR Electronics. In quantity 10, they are



FOUR DIGIT, 12 PIN LED CONNECTIONS

1 — Segment E	12 — DIGIT 4
2 — Segment D	11 — Segment A
3 — Decimal Pt.	10 — Segment F
4 — Segment C	9 — DIGIT 3
5 — Segment G	8 — DIGIT 2
6 — DIGIT 1	7 — Segment B

\$1.25 each, which is not too bad. The digits are about a half inch high and have a right hand decimal point after each digit. They didn't come with any specs, but a low voltage power supply and a series resistor showed what the pinouts of the display are (Figure 2).

Now, what if you have trouble finding common anode displays (see the Finding an LED Display sidebar)? There are common cathode displays out there with segments and digits

FINDING AN LED DISPLAY

LED displays don't seem to be sourced by the "old name" OEMs much anymore. I don't know why, but I couldn't find references to them in many of the mail order catalogs that I looked at.

I think that one of the original parts offered was the MSQ6911C from Fairchild. Fairchild has since sold their line to Everlight so you can find documentation for that part at either site.

In the article, I made reference to a display (or a bunch of them) that I purchased from Electronix Express. Their stock number is 08FYT5641B. These devices have a part number of FYQ-5641 B on them. I Googled this num-

ber and came up with a few hits on the search — all in Russian! After looking at the datasheets at www.rct.ru (the titles were not readable, but fortunately schematics and ratings are), it sure looked like the right part. So, although I didn't have the name of the vendor, I was on the right track. These are common anode displays.

A broader search on Google with a reference to just 5641 brought up a lot more hits.

Futurlec sells a part with a reference of 7FR5641BS. This looks like it would sure work.

Hobby Engineering has a part H2276 that cross-references to

Fairchild MSQ6911C.

Jameco has a couple of parts that will work. The orange display (Jameco P/N 335185PS) has a higher luminosity than the green display that they reference as 335193PS. The green display is a little dim in a brightly lit room with this design. I'm sure that it would work well with more current through it and/or a higher duty cycle. It's usable, just not very bright in this application.

So, you have a variety of options on getting one of these displays. In the article, I discuss using either common anode or common cathode displays and you can also use either red or green.

I have a collection of 16F648A PIC microcontrollers. I bought these at a quantity 25 price break and they are my little “go to” microcontrollers. The design could also use the 16F627 and 16F628

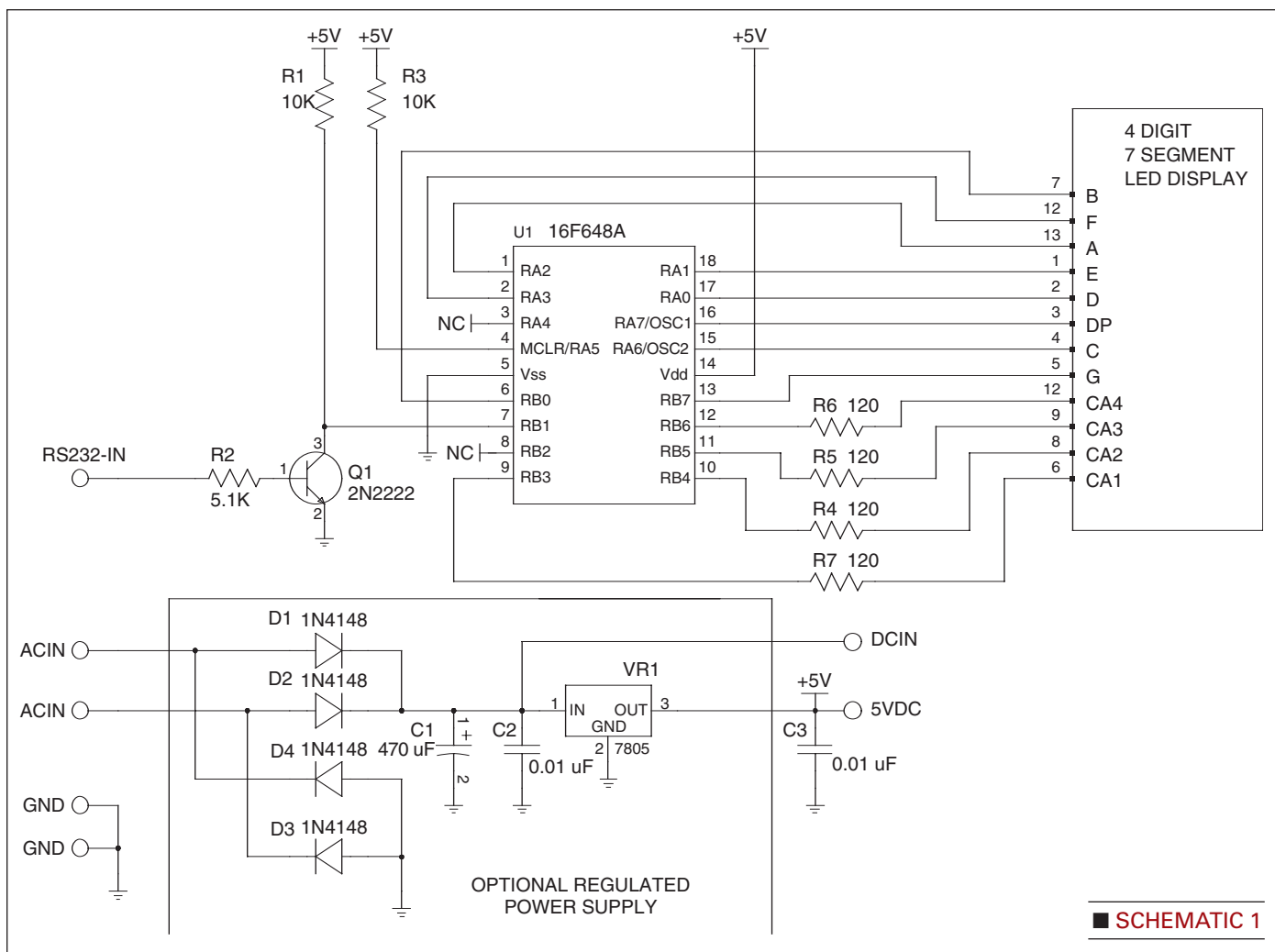
parts. The -A models just have twice as much program Flash memory and they only cost a couple of pennies more than the lower capacity parts, so I typically use these. But if you have some of the other parts, by all means, change the configuration word and the processor type in the source code and use those.

For little designs like this, I often do the printed circuit board design first and then do the schematic. It's a little backwards, but allows for some much simpler layouts. I first lock out the special pins of the PIC (like MCLR, the RS-232 pins, RB4, power, and ground). Then with the pins left over, I connect to the display. To keep the small form factor for the board, I mounted the display on the solder side of the board and the rest of the components on the other side. This means that I could put the PIC inside

the footprint of the display. With a little bit of thought, I got a single-sided board without a jumper.

After doing the layout, I generated the schematic (see Schematic 1). There are four current-limiting resistors for each of the anodes, the microcontroller, and a simple inverter made from a 2N2222 or other general-purpose NPN transistor. This is required for the PIC's serial input. The signal must be inverted (have a low true signal for the start bit). Note that this inverter circuit is not within RS-232 specs, however I have used this circuit with many different serial interfaces without a problem. The power supply is just a full bridge linear regulator design, and without it, there is only the PIC, one transistor, the display, and seven resistors. That's a pretty low parts count!

After the schematic was done, I



could then do the register map for the PIC program and I could start writing code. I've done several PIC projects, so I have snippets of code that I have used to initialize Timer0 and the USART. I've specified 9600 baud for the serial input but you can modify the code to support the baud rate of your choosing. The code uses Timer0 for the time between display changes; I choose around 500 μ s for a flicker free display. The register map is:

```
*****
; PORT A & B I/O definitions for 16F648A version
;
; BIT 7      6      5      4      3      2      1      0
; PORTA      DP      c      MCLR   NC      f      a      e      d
; PORTB      g      CA4     CA3     CA2     CA1    NC      RS232  b
;
*****
```

where DP is the decimal point, a-g are the segments, and CA1-CA4 are the digits. Note that my configuration has the leftmost digit as CA4 while most documentation has it as the rightmost. I do it this way in case I have three digit displays. NC stands for no connection.

There is an assembler define statement that selects either common anode or common cathode displays. If you have a common cathode display, comment out the #define COMMON_ANODE statement and reassemble.

All the real work of the code is done in the interrupt service routines. When Timer0 generates an interrupt, the code goes to the next segment to light or not light, as required. Let's look at a portion of the code to see how we multiplex the display. We will use the common anode design. The code is listed in the LED Segment Selection sidebar.

The segments are stored in an array in general-purpose registers from seg7digit to seg7digit+3 where each byte represents a digit. There is a pointer (modulo 4) named this_digit, which rolls from 0, 1, 2, 3, 0, 1... and selects which digit we will display. The pointer plus the offset address to the base of seg7buffer is added together and put in the field select register (FSR). The contents of the register pointed to by the address in the FSR is read from memory using the INDR (indirect register) and placed in the W register. Then this value is held in the register, decoded_digit. This has all eight segments for the current digit we are displaying.

There is also a bit mask register named this_segment. This has the "bit selector" for the or operation to isolate the bit, by shifting a zero through a field of ones. The result of the logical-or operation is mostly ones. For the selected bit, and the decoded digit, if both bits are low, then the output of that bit will be low, driving the cathode for that segment low and the ones in the other bits will leave the other cathodes high (hence, no current will flow). So, we will have, at most, only one segment lit at any one time.

For the common cathode design, the voltage levels are reversed, so we have to perform a logical-and function in a field of ones with a mask of mostly zeros. The result of the and operation is mostly zeros. For the selected bit and the

LED SEGMENT SELECTION

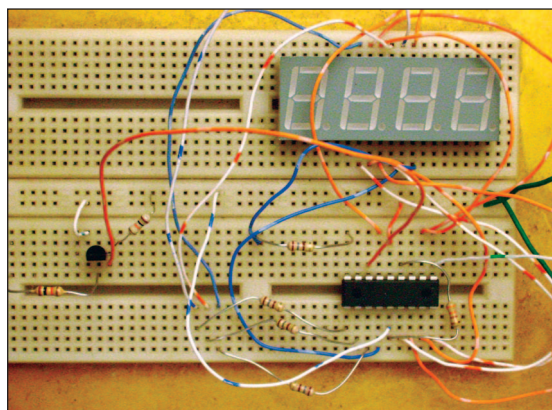
NOTES:

- 1) Only the common anode code is shown for clarity. Refer to the source code for additional details.
- 2) The seven-segment values have been stored in seg7digit buffer, NOT bcd values. They are converted while in the serial interrupt service routine.
- 3) Turning on the common anodes is done outside this code and is not shown.

```
;-----
; update the LED display with the new values.
; this is done on about a 500 microsecond rate to allow for all
; 32 iterations through the display.
;-----
; set up to do the next segment
bsf      STATUS,C          ;set carry bit
rlf      this_segment,F    ;set up next segment
btfsc    STATUS,C          ;see if we have rotated through
goto     led_update100     ;still working on this digit
; here if we have rotated through all segments of the current digit
; set up for next digit.
movlw    B'11111110'
movwf    this_segment
incf     this_digit,F
movlw    B'00000011'
andwf    this_digit,F      ;modulo 4 increment
movf     this_digit,W      ;hold digit as pointer offset
addlw    seg7digit         ;add in offset
movwf    FSR               ;use FSR for buffer select
movf     INDF,W            ;hold digit in W
movwf    decoded_digit     ;hold onto value

; Turn off all cathodes and anodes in PORTB
led_update100:
    movlw    B'10000001'
    movwf    PORTB
; Do PORT A
; Turn off ALL cathodes PORTA
    movlw    H'FF'
    movwf    PORTA

; Turn on the selected segment on the display
    movf     this_segment,W    ;get the desired segment
    iorwf    decoded_digit,W   ;and with decoded digit
    movwf    decoded_segment   ;and hold it
```

■ **FIGURE 3** rotate a one into the carry, we are finished with this digit.

The process continues each time we have a Timer0 interrupt.

The code also consists of an interrupt service routine for a character being received from the USART. Refer to the source code for all of the details but it's pretty standard in design: when the USART interrupts

decoded digit, if both bits are high, then the output of that bit will also be high, driving the anode on for that segment.

After setting the cathodes in both output ports, the `turn_on_anode` subroutine is called. This routine then turns on one and only one of the anodes based upon the digit number. This routine is found at the start of program memory as it uses a computed goto for its operation. The PIC is program-page sensitive when doing computed gotos, so I usually stick them at the beginning of memory to avoid page faulting.

If we are using a common cathode, the `turn_on_cathode` subroutine is called. This routine turns the cathode zero rather than the `turn_on_anode`, so it is now sinking current.

If the zero from this segment is rolled into the carry bit, we know we have finished all eight segments of this digit. We reset the mask and put the next digit value into `decoded_digit`. For the common cathode, it's a one in a field of zeros, so if we

with a character received, the interrupt service routine first checks to see if there has been an error in transmission, in which case, the character is ignored. The character is then checked for either a period, blank, or a minus ASCII value. If it is a period, then the decimal point of the last digit (rightmost) is cleared, which will turn the decimal point on, and no shifting of the buffer is done. If the character is a blank, then the code will put all ones into a register named `charin`. Similarly, if the character is a minus, then the code will put a value with the "g" segment lit into the register `charin`.

If neither a period, minus, or blank, then we range check the character for an ASCII value of 0 through 9. If outside this range, then the code ignores the character. If it is in range, the code converts the ASCII character into a BCD value then calls the subroutine `bcd_2_7seg` again found in the beginning of program memory. This computed goto routine converts the BCD value into its corresponding seven segment value. The code will hold this value in `charin`.

Finally, the `seg7buffer` is shifted left one digit and the decoded value held in `charin` is put into the rightmost digit buffer. (The entire program may be downloaded from the *Nuts & Volts* website at www.nutsvolts.com)

Code in hand, I thought I'd best check out the idea on a prototype

board. I used one of those push-in types and you can see the results of this rats nest in Figure 3. Not pretty, and might be prone to open circuits, but should test the theory of operation without having to go through a lot of fabrication for nothing. In fact, I left off the serial input inverter and just loaded up the `seg7digit` buffer with all zeros. This will turn ON all the cathodes and have the display show all 8s with their decimal points set.

This showed that the display was indeed bright enough and that the 180Ω resistors were an adequate choice. Well, not quite. I found a green common cathode display and it was not very bright. Throwing a little more current through each segment with 120Ω proved to be much better.

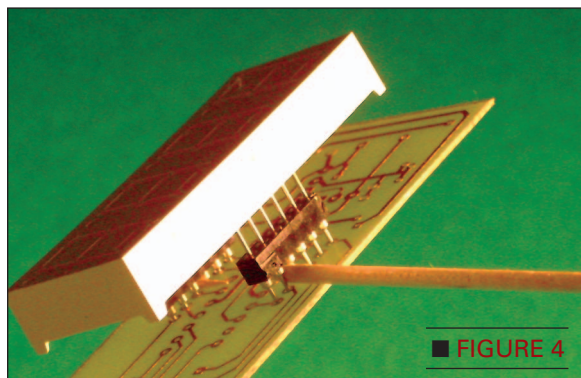
Construction of the printed circuit hardware is straightforward. If you have a DC supply, there's no need to have the bridge rectifier and filter cap. If you have a 5V DC power supply, there is no need for the 78L05 voltage regulator, so you can leave that out, too.

When assembling the board, I suggest that you use a cut up machine pin socket for the display. Cut this socket and remove any supporting holders for the rows to have two six-pin single inline sockets. Put these in the display and put the whole assembly in the board. Raise the assembly with a couple of toothpicks (Figure 4) and you should be able to solder to the pads.

After the single inline sockets have been soldered, remove the display from the sockets and continue with the assembly. No need for a regulated supply for me, so the component view (Figure 5) does not have it populated.

After programming, the PIC needs to be inserted into the board and power applied. Nothing should happen, so don't panic. That's what it's supposed to do!

After the smoke test, you can connect up a serial output port for continued testing. You can use Hyperterminal under Windows or Minicom under Linux. Both use the



■ **FIGURE 4**

serial port of a PC as a terminal emulator. Configure the terminal program for 9600 baud, 8N1. (Note that after configuring the baud rate in the terminal program you may have to exit the program and restart it for the baud rate to go into effect.)

Because I haven't mentioned which pins on the serial cable to connect to the board, some cables have their transmit and receive data lines crossed. For a DB9 type connector, tie pin 5 to the ground of our board. Jumper pin 2 of the DB9 to the base resistor of the inverter transistor. With a logic probe on the collector of the transistor, hit a couple of keys on the keyboard. If the logic probe shows that the collector pulses low, then you have the right pin. Otherwise, try the process again with pin 3 of the DB9. One or the other should work. If not, connect pins 2 and 3 together and type on the keyboard. You should see characters on the screen. If not, there is something wrong with the terminal program. Otherwise, a bit of troubleshooting is required on the board around the inverter.

If you have figured out which DB9 pin to use, then you should be able to type in any of the following keys and see the results show up on the display. If characters 0 through 9 are typed, you should see them one at a time left shifted one digit each time a key is pressed. If you type a blank (space bar) after you have typed a digit, you should see a blank digit in the rightmost position and the visible digit shifted left one position.

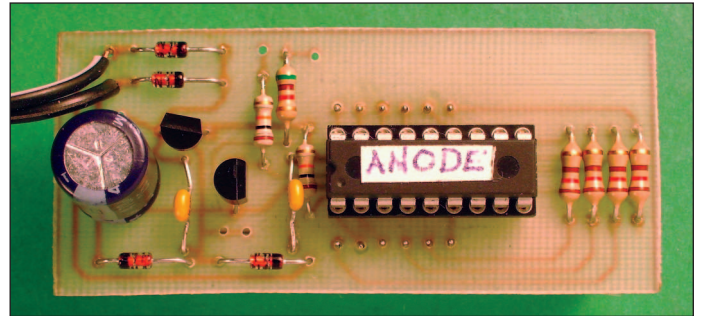
If you type a period, the display does not shift left by one, but the decimal point for the rightmost digit will be lit. The lit decimal point will follow that digit to the left as additional characters are typed in.

Finally, you can type a minus sign and it will show up in the rightmost digit position. That's about it for the operation.

The software on your PC, single board computer, or dedicated microcontroller can now send

■ **FIGURE 5**

numerical data to this remote display in another part of your house or office letting you keep an eye on important information! **NV**



PARTS LIST

REF	QTY	DESCRIPTION
<input type="checkbox"/> C1	1	470 μ F electrolytic (optional)
<input type="checkbox"/> C2	1	0.01 μ F 25V (optional)
<input type="checkbox"/> C3	1	0.01 μ F 25V
<input type="checkbox"/> D1-D4	4	1N4148 diode (optional)
<input type="checkbox"/> Q1	1	2N2222 or general-purpose NPN
<input type="checkbox"/> R1,R3	2	10K Ω 1/4W carbon resistor
<input type="checkbox"/> R2	1	4.7K Ω 1/4W carbon resistor
<input type="checkbox"/> R4-R7	4	120 Ω 1/4W carbon resistor
<input type="checkbox"/> U1	1	PIC (select one): 16F627(A), 16F628(A), 16F648AV
<input type="checkbox"/> R1	1	78L05 +5V regulator (optional)
	1	Common anode or common cathode four digit, seven-segment display



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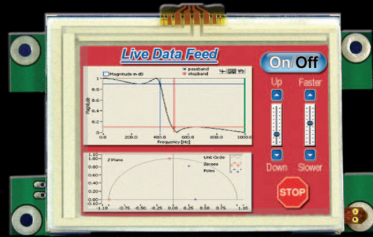
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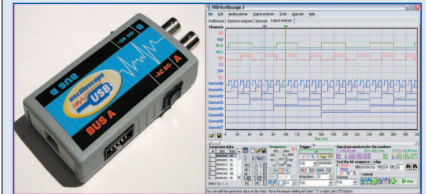
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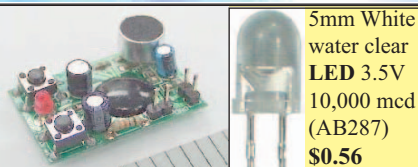
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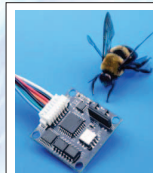
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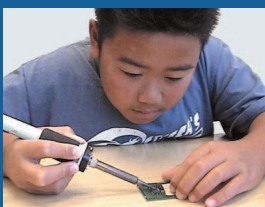
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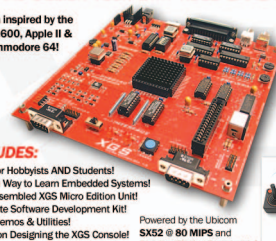
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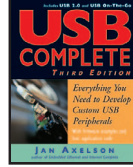
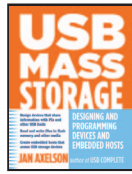
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READER FEEDBACK

Continued from Page 9

electronics. The inverter you mentioned in your email most likely has plenty of power to start and run your furnace. Some considerations about inverters are:

1. Zero or no-load power consumption. In other words, how much power does this inverter draw from a battery when it is simply "on" and not carrying a load. Less expensive inverters will draw anywhere from one-half to one amp of standby current, so if you leave it permanently connected to a battery, it will eventually draw the battery down to nothing unless you are charging it with a charger capable of supplying more than that current. Of course, you can simply disconnect the inverter from the battery when it is not in use to eliminate this problem.

2. Sine wave or modified square wave output. Less expensive inverters employ a digitally-generated approximation of a sine wave at the output. Most AC fan motors are inductive motors and may be particular about the "quality" of the power they receive, especially when starting up. My general experience is that inverters made today are good enough to start even the most picky inductive motors, provided you have enough headroom in the power rating of the inverter you choose. A general rule-of-thumb is if you choose an inverter rated for 200% or more of the motor's power rating, it will probably start reliably. Fan motors have a fairly limited load on them (usually a squirrel cage fan) and are easier to start than say, a refrigerator or air-conditioner motor.

3. Battery life. You want your battery

to be available and up-to-snuff when you eventually need it. This requires putting a quality charger on it — one with a fully automatic cutoff — and you will need to occasionally check on it to make sure everything is working properly and the water levels are correct, etc.

So, in the end, you should find yourself a decent battery charger, deep-cycle battery, and inverter, and with the breakout box I described in the article, you should be able to switch over to battery power on your furnace in less than 10 minutes. I would not recommend leaving the furnace on the inverter as a permanent installation, as this may be hard on your battery, inverter, and possibly your furnace fan motor(s).

I will consider a separate article on

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inverters for the future — thanks for the suggestion!

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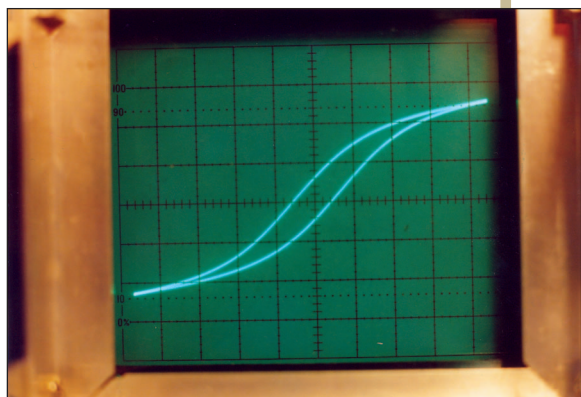
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Some time ago, I built a handy self-contained inductance meter (What the L is it?, *Nuts & Volts*, August '05). It works well, but it registered nothing when I tested some inductors I'd picked up at a hamfest. I set up my old standby — a parallel capacitor, a signal generator, and an oscilloscope — and found these inductors were extremely lossy. As their cores were wound from metal tape, I wondered if they were designed to have square-loop characteristics.

I put together a device to display their behavior. Here it is.



PROBING CORES

Build an Oscilloscope Accessory That Displays the B-H Curves of Inductor Cores

Why Use Cores?

The field induced in a ferro-magnetic core by an applied current can be thousands of times higher than that generated in air by the same winding. Inductors with iron-dust or ferrite cores are much smaller than air-cored ones as they store more magnetic energy in the same space. They need fewer turns of wire so their resistive losses are lower, leading to a higher Q.

Such cores have three disadvantages. One is that if the core material conducts, it behaves like a resistive secondary winding and absorbs input power. Most cores are made either from high resistivity magnetic solids such as a ferrite or from very fine iron dust in a non-conducting matrix. Cores intended to reduce high frequency interference and oscillation are lossy and are unsuitable for tuned filter or DC-DC converter applications.

With a core, inductance depends on the current flowing. It's high for small currents but falls enormously when some threshold — the

saturation current — is reached.

Some cores remain magnetized after the current drops to zero. This effect is known as hysteresis. Early computers used tiny two-state cores to store data bits. At one time DC-DC converters used hysteresis to control their oscillation frequency. My unknown cores might have been intended for that use.

B-H Curves

Saturation and hysteresis can be explored by displaying a core's B-H curve on an oscilloscope. This curve plots the relationship between the magnetic intensity (H) applied to the core and the resulting magnetic flux (B) in the core. It can be displayed on an oscilloscope switched to its X-Y display mode. In a toroid, $H = NI/L$. N is the number of turns, I is the current, and L is the mean circumference of the toroid. Here, N and L don't change so H is proportional to the current.

In this tester, the inductor current is swept linearly above and below zero. This current also drives the oscilloscope's X input. The Y input is made proportional to the magnetic flux. This, as I'll explain, is not measured directly.

In air $B = H$ and the B-H curve

■ **FIGURE 1.** The B-H curve of a just-saturating 470 μ H inductor.

is a straight line with unit slope. The ratio B/H is the relative permeability of the core. It may be as low as five in some dust cores and as much as 5,000 in ferrite cores. The curve is now much steeper; the oscilloscope's Y gain must be readjusted to create a reasonable display.

Typical core materials show a straight line which curves towards the horizontal at both ends (see Figure 1). The curved tips show the core's permeability falling at high currents.

Using the Curves

In many DC-DC converters, a constant voltage is applied to an inductor. Initially, the current increases linearly with time, storing energy in the inductor. When the current reaches the saturation level, the inductance falls and the rate of current increase rises. This increased current stores little additional energy in the inductor but may damage the switching transistor. In DC-DC converters, inductors nearly always operate below their saturation level so this level is essential design information.

Low-loss core materials have a B-H curve in which the positive- and negative-going curves almost match. A loop with a gap between the two traces, as in Figure 2, reveals both core losses and residual magnetization. I'd wound this inductor on a large ring used as an interference suppressor in an

old keyboard.

The B-H Instrument

For clarity, I've split the tester schematic into the ramp current generator (Figure 3) and the core analyzer (Figure 4). The part numbers are sequential across both figures.

The current ramp drives the inductor under test with equal positive and negative peak currents. These are adjustable up to 0.5 amps with switch SW1. A one ohm resistor (R18) in series with the inductor measures the actual current flowing and supplies the horizontal (X) sweep signal for the oscilloscope.

It isn't practical to directly sense the flux in the core so it's calculated

from the coil voltage. Since the rate of current change is constant, this voltage is proportional to the coil's inductance. With a pure inductor, it would be a square wave with positive and negative values proportional to the inductance times the rate of change of the current. If the permeability changes, then so does the inductance and the voltage changes accordingly.

For the oscilloscope's vertical (Y) input, we want a voltage that rises

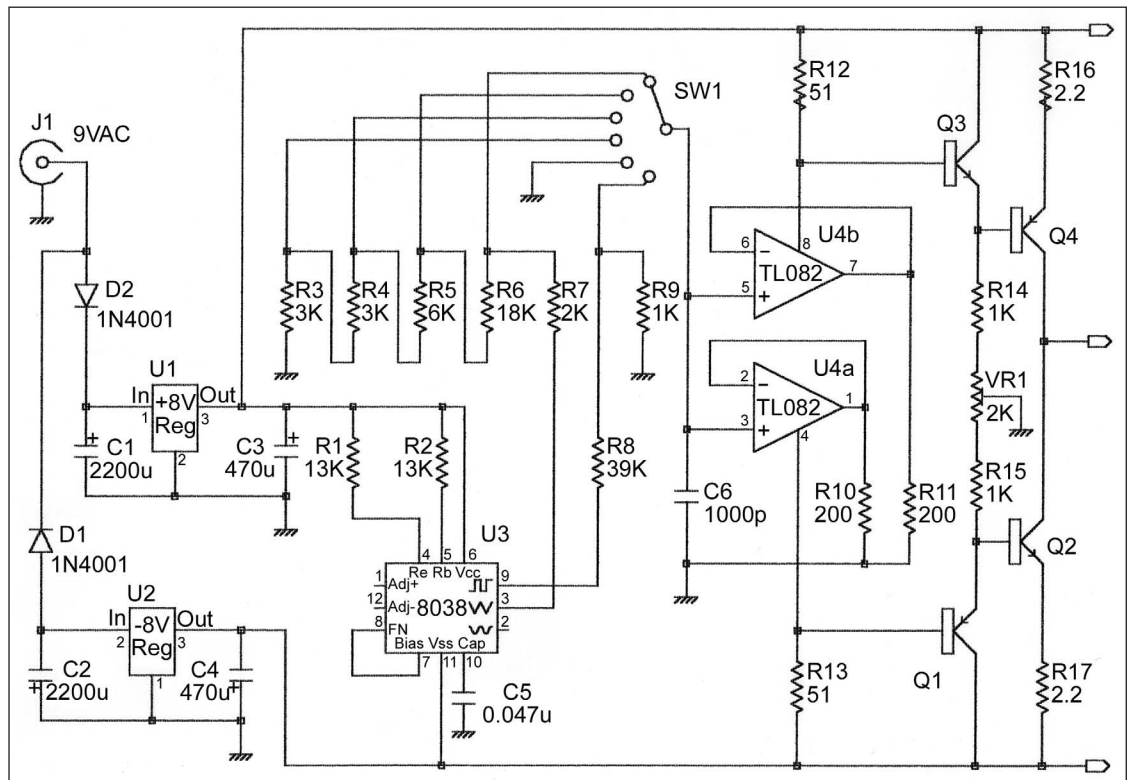
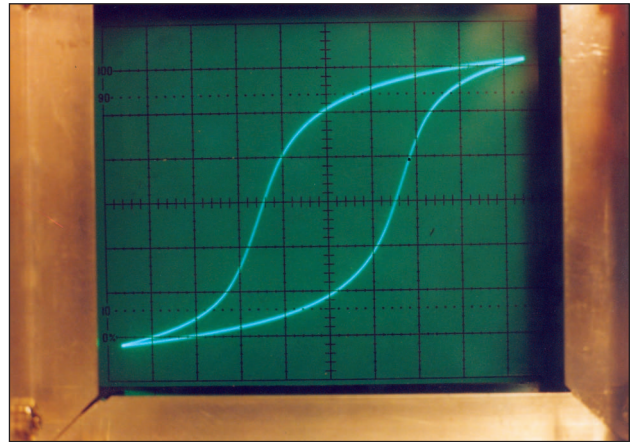
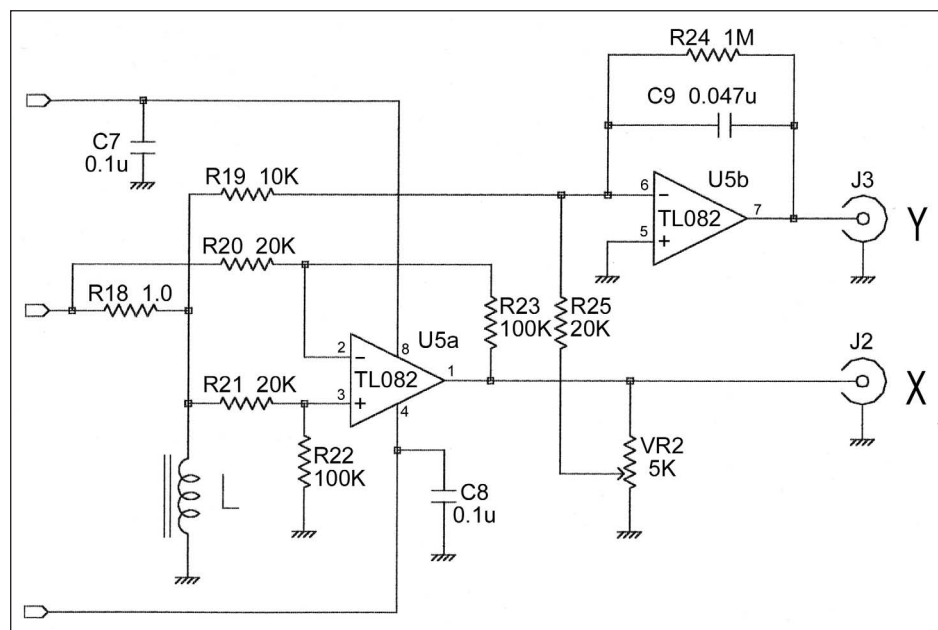


FIGURE 3. The ramp current generator.



■ **FIGURE 4.** A differential amplifier measures the current. An integrator supplies the vertical signal.

reference inductor. As the current ramps down from plus full scale to minus full scale, the inductor voltage becomes -1V, giving the desired 2V peak-to-peak signal. As the test signal ramps up for 1 ms and down for 1 ms, the repetition rate is 500 Hz.

Making a Ramp

I avoided a lot of board clutter by using an ICL8038 signal generator chip (U3) to create the ramp waveform. This chip contains the necessary switched current sources, comparators, and buffer amplifiers to generate a ramp having equal positive and negative peaks. It also has sine and square wave outputs. The latter supplies the test signal for setting VR2.

The ramp length is controlled by two equal resistors and a capacitor. The capacitor (C5) is 0.047 μ F and should be plastic foil, not ceramic. The resistors (R1 and R2) should be 1% types and, ideally, should be matched. The six-way switch (SW1) selects one of four output peak amplitudes: 50 mA, 100 mA, 200 mA, and 500 mA. It also selects the square wave and zero.

Driving Current

An ordinary op-amp can't supply a bipolar current output. Here, I used an old trick. An op-amp drives a load resistor and its power pins supply positive and negative drive currents to a push-pull output stage. The op-amp used should have an output stage with matching NPN and PNP transistors. The TL081 would be ideal, but I only had TL082 (dual) and TL084 (quad) amplifiers in stock. I used both halves of a TL082 and gave each half its own 200 ohm load resistor.

The current driver runs open-loop. I tried feedback from the current-sensing resistor but it was unstable when driving a test inductor. This

linearly to match the increasing current. This is achieved by feeding the inductor voltage to an integrator. This cancels the differentiation of the input current by the inductor. The result is a curve whose slope represents the permeability.

In an integrator, any input offset causes the output to grow without limit. As there should be no net DC voltage across the inductor, the mean Y voltage must be zero. This is emulated by placing a 1 megohm resistor (R24) across the integrating capacitor. This doesn't materially alter the displayed curve but any net DC Y output should be ignored.

Real Inductors

Any real winding has some resistance so the voltage across an inductor has a term proportional to the drive current. Since the X voltage is a linear function of the current, we can subtract a little of it from the coil voltage to correct for the winding resistance. VR2 lets you make this adjustment for windings up to 2.5 ohms. Switch SW1 has a calibration setting which applies a current square wave to the inductor under test.

With the oscilloscope in its normal mode, the resulting Y output should also be a square wave. Any tilt

in its horizontal sections reveals a resistive imbalance that should be trimmed out. In practice, I found I could adjust VR2 to give a plausible B-H display in the normal test mode. Loops whose tips cross themselves show misadjustment.

Design Details

This tester arose from my interest in inductors for small DC-DC converters. Thus, the test range is 10 to 1,000 μ H and the maximum test current is 500 mA. The latter limit let me power the tester from a conventional wall-transformer and to use rather skimpy heatsinking.

The time taken to sweep the current from -500 mA to +500 mA depends on the voltage one wants across the maximum inductance. I chose the peak-to-peak voltage for a 1 mH inductor to be 2V.

A voltage (V) across an inductor (L) causes the current through it to increase at V/L amps per second. One volt across 1 mH causes a 1 A/ms current change. The opposite also applies; a 1 A/ms rate of current change induces 1V across a 1 mH inductor.

The maximum test current ramps from -0.5A to + 0.5A in 1 ms. This induces a +1V signal across the

version assumes that the op-amp's output and supply currents change in step and that the driver stage has a well-defined gain. It uses modified PNP and NPN current mirrors.

Each power transistor (Q2 and Q4) has a large emitter resistor that drops over a volt at the current peaks. These transistors are driven by opposite polarity emitter followers so the base-emitter voltages of each pair roughly cancel. The drivers' bases are connected to the amplifier's power pins and to the power rails via 51 ohm resistors (R12 and R13).

The current gain of this combination is 23. Apart from about 3 mA of static current, the amplifier's power currents equal the current flowing through its combined 100 ohm load. That is, a 100 mV amplifier input generates 23 mA at the driver output. SW1 selects a suitable drive voltage for each current range. C6 reduces noise and stray feedback and makes the current ramp much cleaner.

The op-amp's static current causes the output transistors to pass nearly 100 mA when the output current is zero. I tried reducing this, but only introduced cross-over distortion. We must just live with about 1.6 wasted watts. The regulators' and transistors' peak dissipation is around 5W, but no heroic heatsinking is required.

The output transistors' base currents are adjusted to balance out offsets. Short the inductor terminals and set the switch to its grounded input position. Measure the voltage across R18 with a multimeter on its 200 mV scale and adjust VR1 until the meter reads zero. The specified output transistors have current gains exceeding 150 at 500 mA. Many popular power transistors have lower gains and won't work unless R14, R15, and VR1 are reduced to supply more base current.

Why Eight Volts?

The current driver doesn't need more than about $\pm 2V$ of output com-

■ **FIGURE 5.** The unboxed B-H tester board.

pliance, so bipolar 5V power rails might have sufficed. However, at a current peak the input to the current mirror is 1.3V less than the positive or negative power rail. If the main power were $\pm 5V$, the net supply to the op-amp would be about 8.5V. Since the TL082 is rated for 10V minimum, I boosted the power rails to $\pm 8V$ to avoid risking odd non-linearities. This means hunting down 7808 and 7908 three-terminal regulators. By the way, I used 2,200 μF reservoir capacitors for space reasons, 4,700 μF ones would be better.

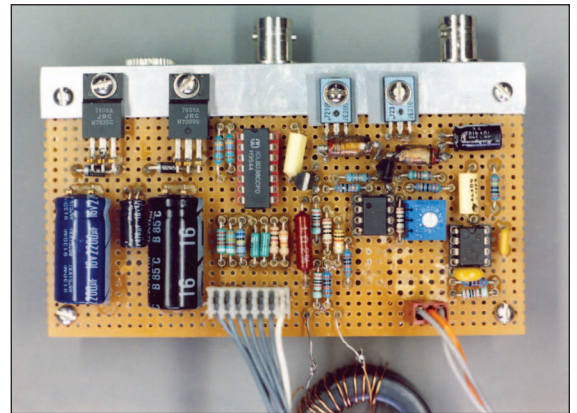
I/V Sensing

One end of the inductor under test is grounded. This makes measuring the voltage across it easy, but you need a floating current-sensing resistor (R18). A differential amplifier (U5a) drives the scope's X input with a scale factor of 5V per amp. The inductor voltage goes to the integrating amplifier (U5b) whose output drives the scope's Y input. As mentioned above, an adjustable amount of the X voltage is fed to the integrator input to compensate for the inductor's winding resistance.

The control switch has an off position that shuts off the ramp generator. Ideally, it should be put in this position before removing the inductor under test. The output voltage swings from one power rail to the other if you don't.

Construction

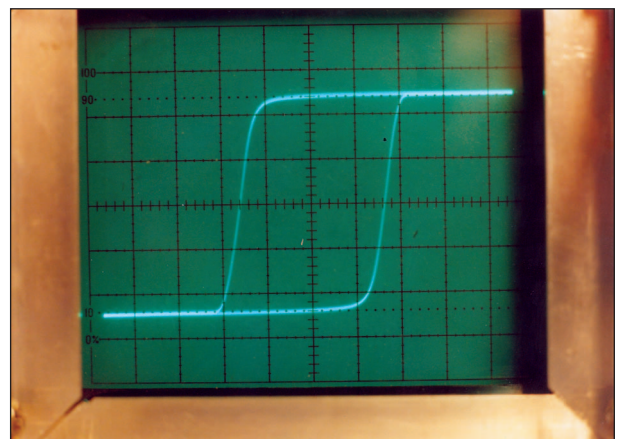
I built this project on a piece of perforated board (see Figure 5), intending to put it into a



plastic or metal box at a later date. I'd already cut a 2.5" by 4.6" board, so I juggled things to fit. To simplify making changes, I used wire-wrap sockets for all the small components. This adds considerably to the board height and you might be more comfortable using PC sockets and sleeved bus wire.

The back edge of the board is fitted with a length of 0.5" by 0.75" aluminum angle. This supports the power input socket and the two BNC sockets that connect the unit to the oscilloscope. It also acts as a heatsink for the power regulators and the two output transistors. If you put the board in a case, this angle fits flush against one wall so use a metal box.

Power comes from a 9 VAC wall transformer. Mine is an old RadioShack one rated at 780 mA. These ratings are about the minimum acceptable for this application. If you use a 12 VAC or higher voltage transformer, you'll need a bigger heatsink.



■ **FIGURE 6.** As suspected, my metal tape cores show a square loop.



PARTS LIST

Item	Description	Item	Description
□ U1	+8 V regulator, 7808, JRC	□ R5	1% resistor, 6.04K
□ U2	-8 V regulator, 7908, JRC	□ R6	1% resistor, 18.2K
□ U3	Function generator, ICL8038, Harris	□ R7	1% resistor, 2.21K
□ U4	Dual op-amp, TL082, TI	□ R8	5% resistor, 39K
□ U5	Dual op-amp, TL082, TI	□ R9	5% resistor, 1K
□ Q1	PNP transistor, 2N3906	□ R10	1% resistor, 200 ohm
□ Q2	NPN power transistor, MJE200, ON Semiconductor	□ R11	1% resistor, 200 ohm
□ Q3	NPN transistor, 2N3904	□ R12	1% resistor, 51.1 ohm
□ Q4	PNP power transistor, MJE210, ON Semiconductor	□ R13	1% resistor, 51.1 ohm
□ D1	1A rectifier, 1N4001	□ R14	1% resistor, 1.0K
□ D2	1A rectifier, 1N4001	□ R15	1% resistor, 1.0K
□ C1	Electrolytic capacitor, 2,200 μ F 16V	□ R16	2% resistor, 2.2 ohm 0.5 W
□ C2	Electrolytic capacitor, 2,200 μ F 16V	□ R17	2% resistor, 2.2 ohm 0.5 W
□ C3	Electrolytic capacitor, 470 μ F 10V	□ R18	2% resistor, 1.0 ohm 0.5 W
□ C4	Electrolytic capacitor, 470 μ F 10V	□ R19	1% resistor, 10.0K
□ C5	Plastic capacitor, 0.047 μ F 50V	□ R20	1% resistor, 20.0K
□ C6	Ceramic capacitor, 1,000 pF 50V	□ R21	1% resistor, 20.0K
□ C7	Ceramic capacitor, 0.1 μ F 50V	□ R22	1% resistor, 100K
□ C8	Ceramic capacitor, 0.1 μ F 50V	□ R23	1% resistor, 100K
□ C9	Plastic capacitor, 0.047 μ F 50V	□ R24	1% resistor, 1.00 M
□ R1	1% resistor, 13.0K	□ R25	1% resistor, 20.0K
□ R2	1% resistor, 13.0K	□ VR1	Trimmer, 2K
□ R3	1% resistor, 3.01K	□ VR2	Variable resistor, 5K
□ R4	1% resistor, 3.01K	□ L	Inductor under test
		□ SW1	Six-way switch
		□ J1	Coax connector to PSU
		□ J2	BNC connector (X output)
		□ J3	BNC connector (Y output)
		□ 9 VAC	800 mA wall-transformer

The inductor under test can be connected with banana-pin screw terminals. You can get away with a

foot or so of test lead between the tester and the inductor; we're not talking RF here.

higher currents, but I'll leave that development to the more intrepid readers. **NV**

Applications

This tester can be used to analyze a core material or to evaluate a finished inductor. In the former case, as many or as few turns as one needs may be put on the core. Use the highest test current to avoid winding more turns than necessary. The loop's Y voltage depends on the inductance so you may run out of scope gain if you try to test very small inductors. The results you get tell you what type the core is. As Figure 6 shows, my unknown cores were definitely square-loop devices.

When testing a pre-wound inductor, the parameter of interest is its saturation current. The test currents let you focus in on the most interesting part of the curve. Some inductors may not saturate even at the highest test current. This design could be adapted to considerably

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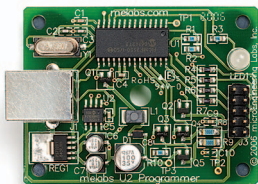
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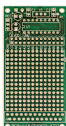
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Stereo VU and Peak Meter Kit

KC-5447 \$40.75 + post & packing

Accurately monitor audio signals to prevent signal clipping and ensure optimum recording levels. This unit is very responsive and uses two 16-segment bargraphs to display signal levels and transients peaks in real time. There are a number of display options to select, and both the signal threshold and signal level calibration for each segment are adjustable. Kit supplied with PCBs, LCD and all electronic components. Accuracy within 1dB for signals above -40dB.

• Case not included use HB-6082 \$5.50

Requires 9-12VDC Wall adapter use Jameco #252751 \$12.05

Short form kit



Battery Zapper MKII

KC-5427 \$58.00 + post & packing

This kit attacks a common cause of failure in wet lead acid cell batteries: sulfation. The circuit produces short bursts of high level energy to reverse the damaging sulfation effect. This new improved unit features a battery health checker with LED indicator, new circuit protection against badly sulfated batteries, test points for a DMM and connection for a battery charger. Kit includes case with screen printed lid, PCB with overlay, all electronic components and clear English instructions. Suitable for 6, 12 and 24V batteries

• Powered by the battery itself

Improved model for 2007



50MHz Frequency Meter MKII Kit

KC-5440 \$40.75 + post & packing

This compact, low cost 50MHz Frequency Meter is invaluable for servicing and diagnostics. This upgraded version, has a prescaler switch which changes the units from Mhz to GHz, kHz to MHz and Hz to kHz, and has 10kHz rounding to enable RC modellers to measure more accurately. Kit includes PCB with overlay, enclosure, LCD and all electronic components. Other features include:

- 8 digit reading (LCD)
- Prescaler switch
- Autoranging Hz, kHz or MHz
- 3 resolution modes including 10kHz rounding, 0.1Hz up to 150Hz, 1Hz up to 16MHz and 10Hz up to 16MHz



Jacob's Ladder High Voltage Display Kit

KC-5445 \$23.25 + post & packing

With this kit and the purchase of a 12V ignition coil (available from auto stores and parts recyclers), create an awesome rising ladder of noisy sparks that emits the distinct smell of ozone. This improved circuit is suited to modern high power ignition coils and will deliver a spectacular visual display. Kit includes PCB, pre-cut wire/ladder and all electronic components.

• 12V car battery or 5 Amp DC power supply required



Powertool Battery Charger Controller

KC-5436 \$23.25 + post & packing

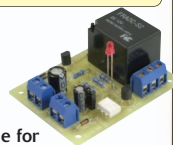
Enhance the performance of the charger supplied with your power tool with this controller. It incorporates charge timeout, min and max temperature monitoring, Delta charge detection, power and charge LED indicator, adjustable Delta V, temperature settings, and optional adjustable trickle charge. Suits both Ni-Cd and Ni-MH cells. Kit includes PCB with overlay, case, all electronic components and clear English instructions.



DC Relay Switch

KC-5434 \$8.75 + post & packing

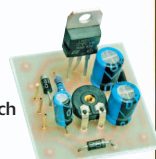
An extremely useful and versatile kit that enables you to use a tiny trigger current - as low as 400µA at 12V to switch up to 30A at 50VDC. It has an isolated input, and is suitable for a variety of triggering options. The kit includes PCB with overlay and all electronic components with clear English instructions.



Voltage Regulator Kit

KC-5446 \$8.75 + post & packing

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Ignition System

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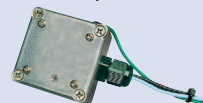


Ignition Coil Driver

KC-5443 \$26.00 + post & packing

Add this ignition coil driver to the KC-5442 Programmable Ignition System and you have a complete stand-alone ignition system that will trigger from a range of sources including points, Hall Effect sensors, optical sensors, or the 5 volt signal from the car's ECU. Kit includes PCB with overlay and all specified components.

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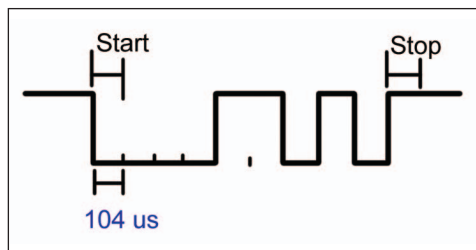


Microcontrollers (MCUs) can be classified in many ways by different criteria. But, for this article, we will divide them into only two categories:

the ones that already have a built-in serial port and the ones that don't.

We all know the importance of serial data communications to our daily life and the convenience of using microprocessors in achieving this goal. So, what do you do if you have a microcontroller that does not have a built-in serial port?

■ FIGURE 1. Transmit "X."



CREATE YOUR OWN SOFTWARE SERIAL PORT

Using Bit-Banging Techniques

The answer is not to abandon it, nor avoid using it. But rather, to create a software serial port for it. This is not as daunting a task as you might think. It only takes some time to learn and try. You will find the results are very interesting and rewarding.

I will present two practical examples to show — from simple to complex — how easy (or how difficult) it is to do so. First, let's review the serial port.

Serial Port Basics: 9600 bps, 8N1

We're all familiar with a PC serial port. Compared to a parallel port, the main difference is it transmits data one bit at a time. (That can save a bunch of wires!) So, there are only two wires needed: TX (transmit) and RX (receive) for data transmission. Actually, a common ground (GND) wire is needed, as well.

The CPU of a microprocessor does not handle data one bit at a time (it's too inefficient!), so the task of serial data transmission is relegated to a special hardware part called a UART (Universal Asynchronous Receiver/Transmitter).

The UART is the heart of a serial

port, where a mechanism is provided to convert a byte into a series of bits for transmission, and vice versa for reception. To make this happen, first and foremost, the UART must have an accurate bit rate (baud rate) generator. The serial port speed is defined in bits per second (bps) and is governed by the baud rate generator.

Of course, the UART also has other hardware to check for transmission status and errors, flow control, etc. But the essential parts are the above-mentioned three in order to get it up and running.

Each byte of data is transmitted in this sequence: Bit 0 or the least significant bit (LSB) first, then bit 1 through bit 6, then finally bit 7 or the most significant bit (MSB) last. In order to signify the beginning and end of each byte transmission, the RS-232 protocol adds a start bit before the LSB, and a stop bit after the MSB. The start bit is a logic low (0); the stop bit is logic high (1). Figure 1 shows how an ASCII "X" (0x58 hex or binary 01011000) character is transmitted; notice the sequence is reversed to 00011010.

In its simplest and most popular use, the serial port is configured as 9600 bps, 8N1. That means the baud

rate is 9600 bits per second, data is eight bits in one transaction, there is no error checking, and one start bit and one stop bit are attached to each transaction. So, it actually transmits 10 bits instead of eight bits for a byte of data.

A Simple Hardware and Software Implementation

The Atmel ATtiny11 is an inexpensive MCU (only 52 cents each or \$38/100). It's an eight pin chip, without a built-in serial port. However, using the circuit shown in Figure 2 and the simple assembly language program in Listing 1, we will show that a working serial port had been created for it.

This circuit is simple enough to build it on a breadboard. The LED is not required; it only serves as a reminder if you forget to plug in the power supply and the circuit is not working. Furthermore, you can even dispense with the 1 MHz crystal (XTAL) and use the chip's internal 1 MHz RC-oscillator instead. Either way, the demo still works.

Refer to both Figure 2 and Listing 1 and notice that ATtiny11 pin 7 (PB2) is configured as RX, and pin 6 (PB1) is TX. The Dallas Semiconductor's DS275 is a voltage level shifter which shifts the TTL level to an RS-232 level, and vice versa.

J1 is a female DB-9 connector. Only three wires are necessary to connect to the PC serial port and match its DB-9 male connector. You can use three longer wires starting from the breadboard and directly plug each end of wire into the female connector's corresponding pin holes. This facilitates the connection between the DB-9 and breadboard.

Now let's look at the software program in Listing 1. It contains four sections. The first section starting at RESET is the main program. The remaining sections are three subroutines; their detailed executions will be analyzed later, but note that each subroutine corresponds to an essential part of the UART: bit rate generation, transmission, and reception. So, we have a software UART here.

To program the ATtiny11, you first assemble the source code using Atmel's free assembler:

```
AVRASM -I UARTAVR.ASM
UARTAVR.LST UARTAVR.HEX
```

Then you use an ATtiny11 programmer (such as the one published in the February '06 issue of *Nuts & Volts*). You can download all UARTAVR files from the *Nuts & Volts* website (**www.nutsvolts.com**). Notice that the size of this demo program is quite small – it only takes 94 bytes of program memory.

By the way, if you don't have an ATtiny11 or its programmer, but you have an AT90S1200 (which is a 20-pin Flash MCU and doesn't have a built-in serial port), you can still use the same program source code. The only change you need to make is in Figure 2; change component U2 to AT90S1200 and the corresponding pin numbers.

Any Windows PC has a terminal emulation program called HyperTerminal, which is the one we will use to interact

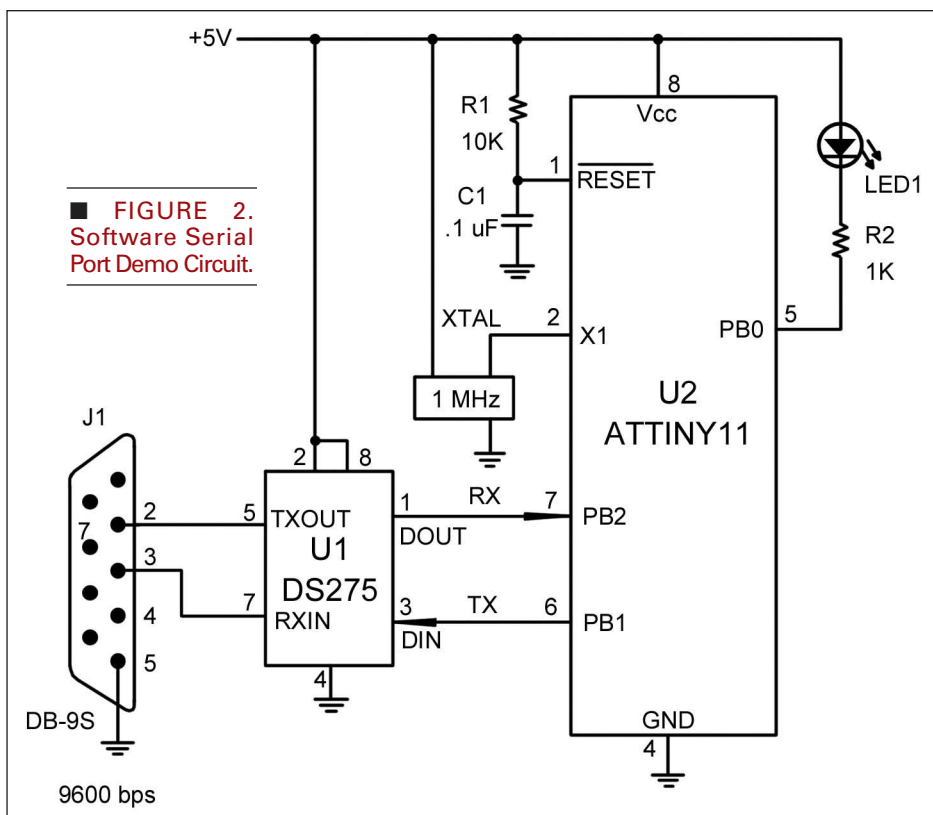
with the demo circuit. From the Windows Start button, go ahead to HyperTerminal and configure it as connected to: COM1(or COM2), 9600 bps, 8N1. When the HyperTerminal window along with a "-" cursor appears, it's ready to go.

Power-up the demo circuit. You'll see an "X" appear on the screen. Typing any character from the keyboard will be echoed on the screen (that's what the program is expected to do). At this point, the software serial port is functioning okay.

Timing is Everything

First and foremost, the UART program must have a way to generate bit rates. This is done by calling the DLY49us routine, which delays 49 microseconds (μ s).

Why go with a 1 MHz crystal? Because at a 1 MHz frequency, one clock cycle = 1 μ s, and for all AVR MCUs, most of their instructions take just one clock cycle (or 1 μ s) to execute. This makes the timing





LISTING 1. Software Serial Port Demo Program.

```
; UARTavr.ASM: 1 MHz AVR BitBanging UART Demo Program (9600 bps, 8N1)
; Interact with PC software: HyperTerminal
; 8/12/2006 Result: "X" echoed, and it works for both Tiny11/1200

.equ    RX = 2          ; RX is PB2: pin7 of Tiny11, pin14 of 1200
.equ    TX = 1          ; TX is PB1: pin6 of Tiny11, pin13 of 1200
.equ    LED = 0         ; LED is PB0:pin5 of Tiny11, pin12 of 1200

.def    RCVREG = R17
.def    XMTREG = R18
.def    COUNT = R19

.include "TN11def.inc"      ; Port definitions for ATtiny11
.cseg
.org 0
;
RESET:
    cbi    DDRB, RX        ; config DDRB bit-2 as Input
    sbi    DDRB, TX        ; config DDRB bit-1 as Output
    sbi    DDRB, LED       ; config DDRB bit-0 as Output
    NOP
    cbi    PORTB, LED      ; LED=ON (active Low)
    sbi    PORTB, RX       ; \
    sbi    PORTB, TX       ; / initialize RX/TX as High

    ldi    XMTREG, 0x58    ; this is ASCII "X"
    rcall  XMT_CHR         ; send "X" to PC at beginning

Main:
    rcall  RCV_CHR         ; recive Chr from Port RX line
    mov    XMTREG, RCVREG
    rcall  XMT_CHR         ; transmit Chr to Port TX line
    rjmp   Main

;
DLY49us:                                ; 49 us Delay (~Half_BitTime)

    ldi    R20, 14        ; 1us
LOOP1:
    dec    R20            ; 14 * 1 = 14
    brne   LOOP1          ; 13 * 2 + 1 = 27
    ret                                ; 4 + 3 = 7

;
XMT_CHR:
    ldi    COUNT, 8       ; 8-bit Data
    cbi    PORTB, TX       ; StartBit='0'
    rcall  DLY49us        ; ~Half_BitTime
    rcall  DLY49us        ; ~Half_BitTime

NEXTX:
    lsr    XMTREG          ; shift right LSB to Carry
    brcc   FORWARD
    sbi    PORTB, TX       ; set TX='1' if Carry='1'
    rjmp   F2

FORWARD:
    cbi    PORTB, TX       ; set TX='0' if Carry='0'

F2:
    rcall  DLY49us        ; ~Half_BitTime
    rcall  DLY49us        ; ~Half_BitTime
    dec    COUNT
    brne   NEXTX

STOPBIT:
    sbi    PORTB, TX       ; StopBit = '1'
    rcall  DLY49us        ; ~Half_BitTime
    rcall  DLY49us        ; ~Half_BitTime
    ret

;
RCV_CHR:
    LDI    COUNT, 8       ; 8-bit Data
wait:
    sbic   PINB, RX       ; wait for StartBit='0'
    rjmp   wait
```

continued ...

calculation much easier.

Now take a closer look at DLY49us. This routine uses only four instructions. From the AVR datasheet, you can find out how many clock cycles each instruction takes. (The calculation is listed there.) The total delay time is exactly 49 μ s.

This routine is used to "waste" 49 μ s when it is needed by the UART. For a baud rate of 9600 bps, a bit is $1/9600 = 104 \mu$ s. We always want to sample the incoming bit in its middle (to minimize any jitter error), so we need to delay one half of this value, or 52 μ s. This is named the half_bitime.

Notice that 49 μ s is not equal to, but a little less than half_bitime; we may call it "almost half_bitime." The reason for keeping a difference between 49 μ s and 52 μ s will be explained in the next section.

How Bit-Banging is Done

Let's look at the XMT_CHR routine which transmits a byte of data loaded in register R18 or XMTREG to the outside world, one bit at a time. Read the code line by line; it's pretty straightforward.

At the beginning, it pulls the TX line low and delays two 49 μ s periods to signify a start bit. After that, register R18 is shifted right one bit, with the LSB going into the carry flag. Depending on whether the carry flag is now set or clear, the TX pin will be set or cleared accordingly. Then we delay two for 49 μ s periods (one bit time). This effectively transmits a high or low bit out.

The above shifting process is repeated eight times until count equals zero, handling the entire byte. The TX line is then set high for two 49 μ s periods to signify a stop bit — the end of transmission.

Because there are several instructions executed between bits transmitted, each instruction takes 1 or 2 μ s in this routine, and the bit output logic is not fixed (due to different bit values at different times). In order to keep the baud rate of 9600 bps or a bitime of 104 μ s, the delay routine must account

for these instructions execution time. That's why we created DLY49us.

Similarly, the RCV_CHR routine receives a byte of data from the outside world and stores it in register R17 or RCVREG. The receiver keeps sampling its RX line until a logic low is detected; that is the beginning of start bit.

To find out the value of LSB, the routine pauses for three DLY49us. By doing so, it samples the middle of the LSB. This is the best position for correct sampling. The incoming bit value is read and the carry bit is set or cleared accordingly. The instruction ROR RCVREG rotates that bit into register RCVREG bit7 each time, until all eight bits are transmitted and count equals zero, so RCVREG has converted the bits into a byte.

The technique of converting a byte into a series of bits for transmission, or converting a series of bits into a byte for reception, is known as "bit-banging."

A Full-fledged Application: WWLSEEP-1 Programmer

You might think that even though the above demo program works in simple cases, it may not work in more complex ones. I had the same concern. I have not seen any other product that's built using a software serial port; all I've seen are just simple demo circuits. I was determined to give it a try, however, I decided to make an I²C EEPROM programmer.

Atmel has two very similar MCUs: the AT90S1200 and the AT90S2313. Both are 20-pin chips; the differences are the 2313 has 2K Flash memory and a built-in serial port; the 1200 only has 1K Flash memory and no serial port.

My strategy was two

Listing 1 continued ...

```

NEXRX:    rcall    DLY49us        ; ~Half_Bitime
          rcall    DLY49us        ; ~Half_Bitime
          rcall    DLY49us        ; at the Middle of next bit

          CLC                    ; clear Carry
          ROR      RCVREG          ; Test RX='0' or '1'?
          sbic     PINB, RX        ; set bit7='1' if RX='1'
          SBR      RCVREG, $80    ; otherwise don't change

          DEC      COUNT
          brne     NEXRX
          RET
;-----
    
```

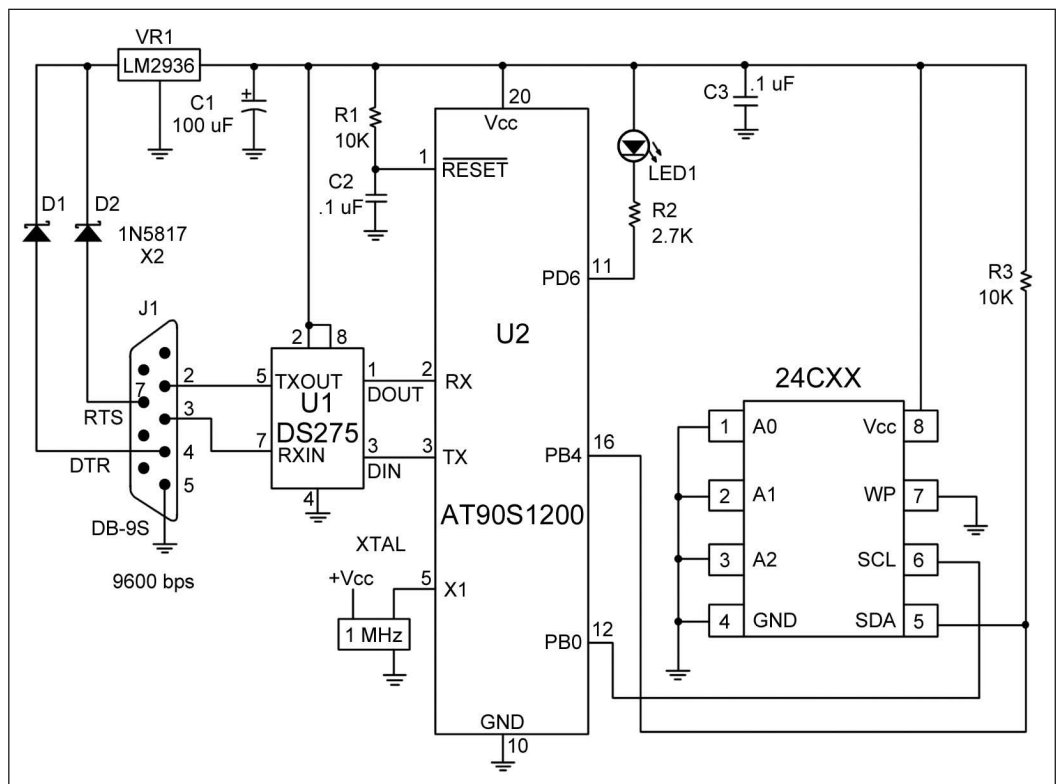
steps: First, build an I²C EEPROM programmer using the 2313, then try to migrate it to the 1200 using my software serial port. It took a few days to complete the first step, however, the migration took much longer than expected. Originally, the 1200's RX and TX pins were not assigned the same pin numbers as the 2313's RX (pin2) and TX (pin3). In experimenting I learned these pins could only get the EEPROM written correctly; reading was incorrect.

I still don't know why it can't read correctly, but I finally discovered that if the 1200 pin assignment was the same as the 2313 (RX to pin2, TX to pin3),

then both reading and writing are correct. The 1200-based programmer completely works this way. The programmer schematic is shown in Figure 3.

Notice this serial EEPROM programmer is wall-wart-less, meaning the power supply is taken from the PC serial port itself. This is convenient to the user. It's possible because the circuit contains only three small chips; the total current consumption is much less than 10 mA.

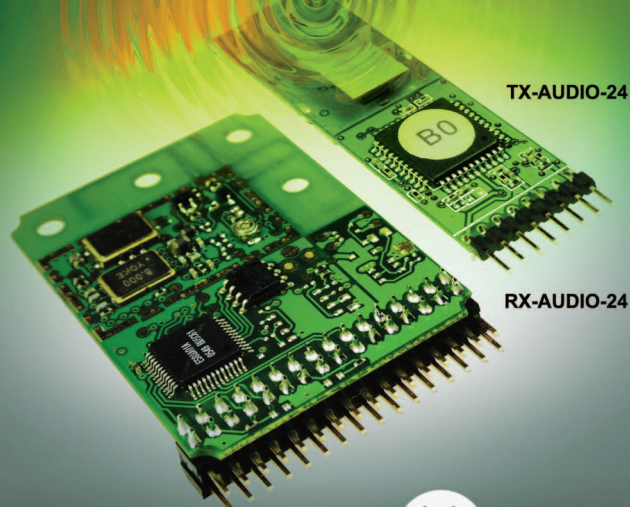
To program the 24CXX I²C EEPROM, only two pins are needed: the serial clock pin SCL and the serial data pin SDA, which is bidirectional. The programming command or data is



■ FIGURE 3. Schematic of Wall-wart-less Serial EEPROM Programmer.

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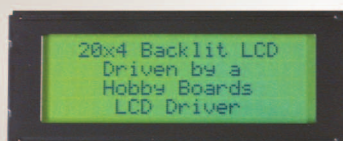
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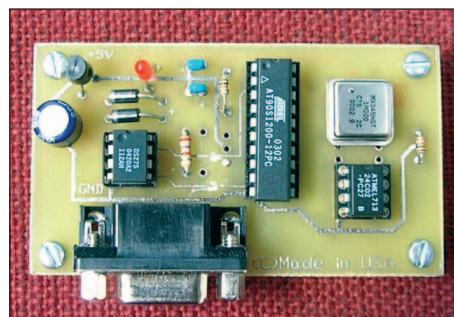
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■ PHOTO 1. This is the WWWLSEEP-1 Programmer.

applied to SDA from the 1200, and the SDA also outputs data to the 1200 when requested. A clock signal generated by the 1200 is applied to synchronize I/O operation.

The complete programmer development project includes writing a Windows XP program to communicate with the programmer, and coding the 1200 firmware. Of course, in addition to creating the software serial port and communicating with a PC, the firmware must perform all read/write programming functions through SCL and SDA. The firmware is 854 bytes total, including the software serial port overhead.

Photo 1 shows the WWWLSEEP-1 programmer. Notice that all the signals and power supply are provided through the DB-9 connector; there is no separate power supply.

Also note that if the PC is not running the programmer software but running the HyperTerminal program instead, it will show the character echo effect as in the first example.

Summing Up

We've seen two examples where a software serial port is useful. It can save you money and it can (nearly) do the same job as a hardware serial port. You'll need some memory space, but the overhead is less than 100 bytes. For the 1K byte 1200, there is still a lot of program space left.

The timing requirement for the asynchronous communication is very forgiving at the 9600 bps speed. Examine to see what will happen if you change the DLY49us to 50 μs by adding an NOP (that's equivalent to 1 μs) to the beginning of the routine. You'll see it is still okay.

Of course, there are limitations. The 1 MHz frequency is too low if you want to get a higher baud rate. At higher speeds the half_btime is reduced and it will be hard to keep sampling in the middle of each bit.

We may not be chip makers, but we can create a software serial port for any MCU when we need it. I have created a website containing the software serial port program source code for different MCUs — just go to www.geocities.com/microappnotes. **NV**

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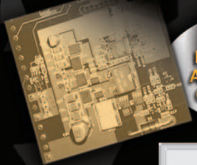
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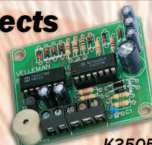
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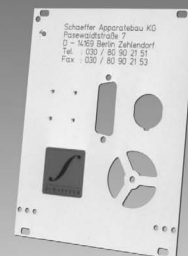
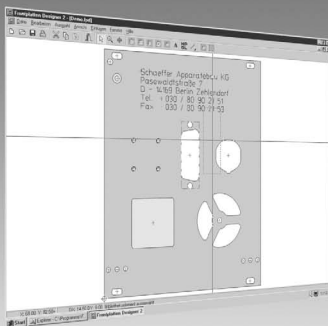
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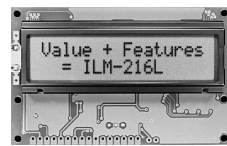
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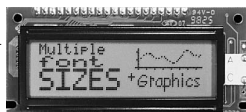
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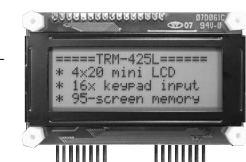
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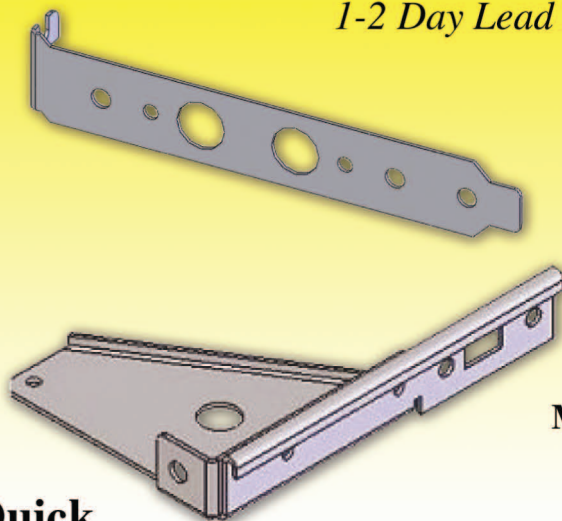
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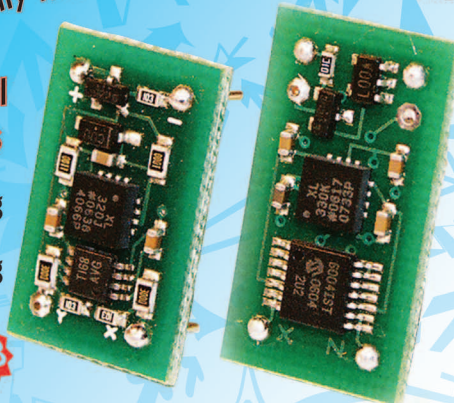
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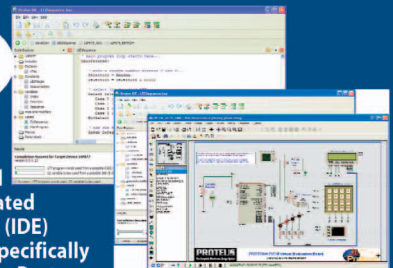
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SONIC REALISM

PART 2

by Gerard Fonte

Why does recorded music sound different from the real thing? When we walk into a room, we instinctively know if the music or speech we hear is live or a reproduction. This seems to conflict with the specifications of the system where distortion and frequency response are nearly perfect. Something important is missing from the recordings that is present in the live recordings. The missing component appears to be phase information. Last time we examined the theory, this time we'll put the theory into practice. Two different speaker systems will be described that you can build.

Previously, it was noted that phase distortion is an aspect to sound that is not generally addressed. This occurs when a sound containing many frequencies is broken up and sent to two (or more) different drivers in a speaker system. This results in two different physical sources for the sound: one for high frequencies and another for low frequencies. This is clearly different from the original instrument or voice which came from a single source (and can usually be treated as a point source).

The major problem with multiple drivers is that sonic reflections from the ceiling, floor, and other large objects in the listening area destroy the phase information. This occurs because of different path lengths for the high frequency and low frequency sound reflections. These sonic reflections can be nearly as loud as the direct signal but do not contain the same phase relationships between the

high and low frequencies.

It was also previously noted that the human sense of hearing is a very complicated system that is extremely sensitive to phase. Both binaural phase (ear-to-ear time difference) and monaural phase (open space sound) variations have been shown to be detectable with as little as 15 microseconds of change. Therefore, it seems reasonable to suppose that a speaker system that could better maintain the phase information regardless of room reflections, would provide a much more realistic acoustical setting.

Phase Coherent Speakers

It is necessary to clarify the issues stated here and the so-called Phase Coherent Speaker systems that are currently available. Most of these systems contain multiple drivers and are designed to provide proper phase

information, but only if measured with a straight line from the speaker to the ear. Any speaker system with multiple and separate drivers is physically incapable of providing proper phase relationships from reflections. Quite simply, if there are two separate sources of sound, phase distortion must occur in any sonic reflection.

Basic Problem

Fundamentally, in order to reproduce the 10 octave range of human hearing (20 Hz to 20,000 Hz), multiple drivers are necessary. Woofers are hopeless when reproducing high frequencies and tweeters simply cannot push enough air to create good bass response. This is especially true when high power levels are employed. (Earphones are not considered because the issue is free-space sound reproduction.)

The technique used is to acousti-

Any speaker system with multiple and separate drivers is physically incapable of providing proper phase relationships from reflections. Quite simply, if there are two separate sources of sound, phase distortion must occur in any sonic reflection.

cally recombine the sounds from the multiple drivers before it leaves the speaker enclosure. In this way, the high frequency and low frequency sounds emanate from a single opening. Thus, sonic reflections from the ceiling will still have the same harmonic phase relationships as the direct line. Note that this provides phase consistency rather than phase accuracy. Phase accuracy is defined as reproducing sounds with the precise phase relationships as they were when they were recorded. Phase consistency is defined as maintaining the proper phase relationships regardless of sonic reflections. The Phase Coherent speakers mentioned above strive for phase accuracy rather than phase consistency. The speakers that are presented here strive for phase consistency rather than accuracy. (As a first step in research, it is reasonable to choose one aspect to determine its relative importance. Designing a phase consistent and phase accurate speaker system is not a simple task.)

The Buried Tweeter Design

The basic design is shown in Photo 1 (note that the wide-angle lens distorts the true shape somewhat). There are two isolated – but identical – rectangular enclosures that each hold a woofer. One woofer is pointed up and can be seen. The second is pointing down and cannot be easily seen. These enclosures are separated with a 9.5 inch gap that is open on three sides (the back is closed). Centered in this gap is a horn tweeter. Photo 2 shows the details of the tweeter assembly as it is partially

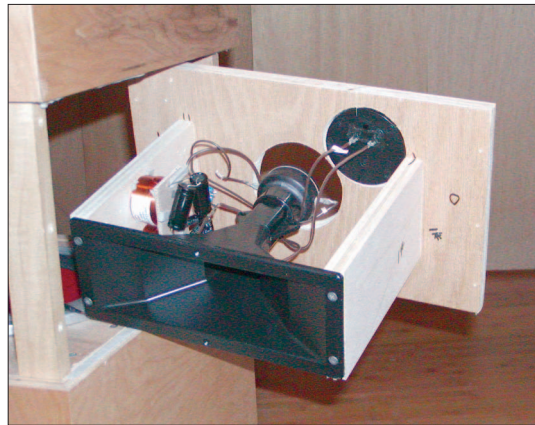


PHOTO 2. The tweeter sub-assembly is partially removed to show the construction method. The crossover network is seen on the left mounting member. The sub-assembly is screwed to the back of the main enclosure.

removed from the speaker enclosure. The cross-over network (2 kHz, four-pole) can be seen attached to the left mounting piece. The black circle to the upper right is the terminal connector. (The hole behind the tweeter was used when testing a longer tweeter.)

The general physical dimensions are 17.25" wide, 15 inches deep, and 51.5 inches tall (excluding feet) with a weight of over 80 pounds. Continuous RMS power at any frequency is 400 watts. However, the woofers are rated at 350 watts each, so the low end is robust. The frequency response characteristics cannot be measured because I have no facilities to do so. I can only state that the performance is certainly acceptable and (to my ears) comparable to other hi-fi speakers I have heard.

Construction details and design rational are provided in the sidebar. There are certainly second-order details that are not directly addressed (off-axis sound versus phase), however, as a first approximation, this design appears to provide the proper physical characteristic that all the



PHOTO 1. The buried tweeter speaker places the tweeter inside the enclosure so that all of the frequencies emerge from a single point. This maintains the phase relationships regardless of reflections. Note that the speaker grill cloth is removed.

different frequencies come out of a single opening.

Performance

The speakers were placed about seven feet to the right and left of the listener. The initial results were not significantly different from conventional speakers. However, there was a subtle difference in some instruments. The placement of these seemed to localize inside the head, like headphones. This effect was not conspicuous.

SONIC REALISM



PHOTO 3. The center channel speaker uses coaxial speakers (seen as two small circles under the grill) to achieve reasonable consistent phase output. This is a much simpler design and can probably be used for the left and right speakers with good results. However, this was not tested. (Note that a trim piece was used to cover the plywood edge.)

channel alone. This should be enough to significantly assist in localization, which should also enhance the reality of the sound.

So, a third speaker was built. However, because of a number of issues (including parts availability) the third, center-channel speaker was much more modest. It is shown in Photos 3 and 4, and consists of a three-way automotive speaker with coaxial drivers. The enclosure is a simple box and is also described in more detail in the sidebar. This center speaker design is much easier, smaller, and much less expensive than the buried tweeter design. It probably would be adequate for the left and right channels, but this has not been tested.

This speaker was driven by a separate amplifier that was just the sum of the left and right channels. (The left and right earphone outputs of the main amplifier were connected together and used as the input for the center channel amplifier.) This speaker was placed about seven feet directly in front of the listener. Note that all the speakers had a direct “line of sight” to the listener. (A rear channel using an out-of-phase left and right mixture has been considered, but not tested.)

The results of this addition were stunning. Excellent sound localization through 180 degrees occurred. When listening to orchestral or choral music, each individual instrument or voice

had a precise and separate location. There was also a depth that placed different instruments in front and behind others. Curiously, all three speakers acoustically disappear. Note that the program material is ordinary stereo CDs and FM broadcasts. (Although some recordings are better than others. This is discussed in more detail below.)

An A/B switch was incorporated to disable the center channel. This provided some interesting information. It appears that it sometimes takes a fraction of a second for the localization to appear and disappear. (Unlike turning a speaker on and off, where the sound is immediately heard or not.) This delay suggests that there is significant mental processing that occurs. This is precisely what was expected and suggested in the previous article: The brain has an auto-correlation function (or its equivalent) that is used for phase analysis.

Speech reproduction is the most important aspect of sonic reality. There are several reasons for this. First, speech is a fundamental aspect of human nature. It is important to us. Speech is also extremely common. We all spend a lot of time each day talking and listening. Finally, unlike most music, speech is mostly heard live. Even at “live” events, microphones and amplifiers are often used. Again, multiple drivers destroy the phase information. Thus, “live” events are actually electronically reproduced stage events. True “live” events are fairly limited. Professional orchestras and amateur/school bands and choirs are the most common. Even jazz is being augmented with electronic amplification. In short, we all know when speech sounds real, but music is a different matter.

It is not surprising that the most dramatic results occur when reproducing voices. When a chorus is reproduced, each voice is distinct and has a precise location. There is also a quality of realism that cannot be

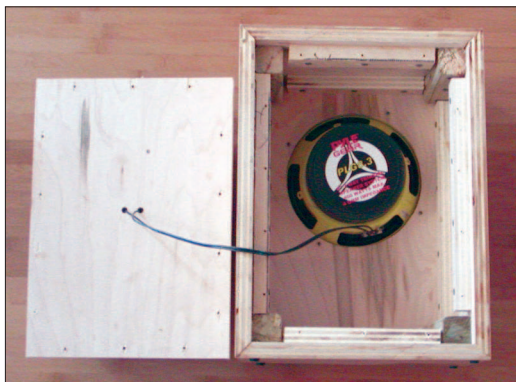


PHOTO 4. The inside of the center channel speaker. This shows the standard construction technique of using internal corner-framing members. Screws and glue are used for every joint (except the back panel) for a solid, air-tight box.

described. It simply sounds as if the choir is in front of the listener. (It is also useful to close your eyes because your brain knows where the sound is coming from. By closing your eyes, there is no conflict between what your eyes and ears are telling you.)

It is unfortunate that there does not seem to be an objective manner in which to measure this effect. However, there are two subtle and unconscious physiological effects that have been noticed when listening to solo singing voices that do not occur with conventional speaker systems. The first is the listener's breathing tends to match the singer's. The second is that the listener tends to mouth the words to the song. Like tapping a foot in time with the music, these effects are variable, but the fact that they do not occur with ordinary speaker systems seems significant.

The last piece of evidence is somewhat more objective. My wife entered the room while I was working at my computer with the stereo on to discuss an unrelated matter. She was not aware of the details of the speakers. A song then started with the words, "Hi. How are you?" She whirled around, clearly startled and said "What ...?" This spontaneous reflexive response is telling. It is, in

BUILDING THE SPEAKERS

Cost and performance were the major issues that were considered when designing the buried tweeter speakers. A closed/sealed box (rather than ported) was required to ensure that all the sounds came from one opening. This required speakers suitable for such an enclosure. The determination of the Thiele/Small parameters necessary for the enclosure were determined with the aid of a modeling program included in the book *Great Sound Stereo Speaker Manual* (2nd ed.) by Weems and Koonce (McGraw-Hill, 2000). This is a very useful book for anyone building speaker systems.

After considerable effort, Sony 12 inch Xplod (XS-L121P5) automotive speakers were selected. These had the proper Thiele/Small parameters and were very attractively priced at a local electronics superstore as close-out items (suggested retail about \$199 each; sale price of \$35 each). These are rated at 350 watts RMS and 1,200 watts peak. The voice coils are only four ohms each, but using two in series provides the standard eight ohm impedance.

The tweeter chosen was a piezo horn driver (Motorola/CTS KSN1142A) attached to a standard diffraction horn. This driver can handle 400 watts RMS and only cost about \$12. Note that horn tweeters generally have much smoother frequency response characteristics than the "Bullet" type circular tweeters. Round dome tweeters have a smoother frequency response but cannot

handle the power. It is difficult to find these KSN1142A tweeters now. High power tweeters are not common.

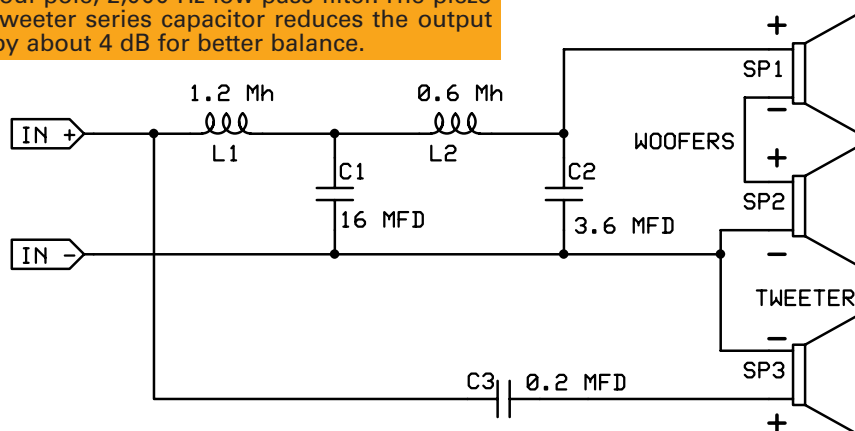
The reason for the use of high-power speakers is the concern about distortion at high output levels. Most home speaker systems are rated at 50-100 watts RMS. However, their distortion increases significantly at half-power or less. Often this is not enough power to provide realistic volume levels. Driving them at half-power makes the music sound "loud" similar to a person's voice when shouting. There is a sonic difference/distortion. With high-power speakers, the music gets louder but doesn't sound as if the speakers are shouting.

The crossover network is technically not required because the piezo tweeter has a high impedance at low frequencies. However, it was desired to keep as little sound of the same frequencies as possible from exiting from both the woofer and tweeter. For this reason a sharp-cutoff, four-pole, 2 kHz crossover network was employed. This is shown in Figure 1.

The enclosure was built with 3/4 inch thick, maple, cabinet-grade plywood. The standard method of screws and glue was employed. All corners used an internal corner-framing member and the screws were driven from the inside (see Photo 4 for an example of the standard internal construction methods). No fasteners are visible from the outside. The top and bottom are mitered to the sides. This involves a three-way miter at each corner. Such a detail cannot be accomplished without the careful use of a table saw. Other simpler methods can be employed but minor changes to the enclosure will be required. The absolute dimensions of the enclosure are not critical and can be varied somewhat. (Enclosure building techniques are presented in the Weems & Koonce book.) Some experience in woodworking is suggested before attempting to build these, or any, speaker enclosures. Sound quality is directly related to construction quality.

The speaker panel was not glued in place so that access was possible to the internal blind screws. However, this panel vibrated at high drive levels. This problem was corrected by placing a piece of weather-seal foam tape between the panel and the mounting members.

FIGURE 1. The basic crossover network for the buried tweeter speaker system is a four-pole, 2,000 Hz low-pass filter. The piezo tweeter series capacitor reduces the output by about 4 dB for better balance.



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SONIC REALISM

CENTER CHANNEL SPEAKER PARTS LIST

Qty.	Description
■ 1	8" speaker three-way Pyle PLG8.3 (no Thiele/Small parameters available) from MCM (#51-1157) about \$46/pair, 200 watts RMS

All panels are 3/4" maple plywood, measurements are outside dimensions, Top, bottom, and side panels have 45 degree miter cuts on two sides (see Photo 4).

■ 2	Front/back panels: 10" x 14.5" (front panel has speaker cutout as required)
■ 2	Side panels: 16" x 8"
■ 2	Top/bottom panels: 8" x 11.5"

Internal corner members

■ 4	6.5" long 2" x 2" (nominal) pine (1.5" actual)
■ 4	1.5" x 11.5" x 3/4" plywood
■ 4	1.5" x 7" x 3/4" plywood
■ 50	1.25" drywall screws (approx.)
■ 25	2" drywall screws (approx.)
■ 4	Speaker mounting screws
■ 1	Wood glue
■ 4	Rubber feet
■ 1	Speaker terminal

fact, the clearest example that, under certain circumstances, sonic reality can be achieved. It should be pointed out that the entire room was visible as she entered, so it was impossible for someone not to be seen. Additionally, the room was on the

second floor and she turned to look towards the outside wall. There was no speaker there.

Recording Hints

Not all recordings provide the

same realism. It seems that the simpler recording techniques, the better. Voices generally sound best if they are natural and free from electronic enhancement. Keeping the microphone about two feet away from the singer helps to create a more natural mix of high and low frequencies (less obvious pops and hisses). If possible, record individual instruments and voices with a single microphone or channel. For multiple people and instruments, use two closely spaced but directional microphones; one for the left and the other for the right channel. Multiple microphone mixing doesn't seem to work too well.

There are several current commercial recording concepts that generally produce good results. These are "Binaural" recordings that use a facsimile of a human head with microphones buried in the ears. The other is the "Qsound™" from Archer Communications. There may be additional techniques, as well. However, it is difficult to find recordings grouped by the engineering technique.

BURIED TWEETER SPEAKER PARTS LIST

Qty.	Description
■ 2	Woofer speakers: Sony Xplod XS-L121P5, 4 ohm impedance, Rdc=3.2, Fs=26.4, Qts=0.42, Qes=0.44, Qms=5.86, Vas=1.96 cu. ft. Rated power=350 watts RMS, 1,200=watts peak, weight=20 pounds.
■ 1	Tweeter driver: Motorola/CTS KSN1142A, 1.8 kHz-30 kHz. Rated power=400 watts RMS.
■ 1	Diffraction horn: 10-5/8" x 3-7/8" x 7-1/4" with 1-3/8" diameter threads @ 18/inch # 54-290 from MCM (www.mcminone.com)
■ 1	Crossover network (see Figure 1)
■ 4	Main vertical struts: 3/4" x 1.5" x 50.5" (actual) maple

All panels are made from 3/4" thick maple plywood. Measurements are outside dimensions. All panel edges (except those at speaker opening and the woofer mounting panels) are cut to 45 degrees.

■ 4	Front/back panels: 17.25" x 21"
■ 4	Side panels: 15" x 21"
■ 2	Top/bottom panels: 15" x 17.25"
■ 2	Woofer panel: 13.5" x 15.75" (with proper cutout for woofer)

Tweeter mounting pieces are made from 3/4" thick plywood, square cut edges.

■ 1	Back panel: 9" x 17.25"
-----	-------------------------

■ 2	Side mounting arms: 9" x 4.5"
-----	-------------------------------

All internal corner members are made from 2" x 2" (nominal) pine (1.5" actual).

■ 8	Front/back members: 14.25"
■ 8	Side members: 10.5"
■ 1	Speaker terminal
■ 100	2" drywall screws (approx.)
■ 30	1.25" drywall screws (approx.)
■ 20	Speaker mounting screws (approx.)
■ 1	Wood glue 8 oz. (approx.)
■ 10 ft.	"Frost King" vinyl foam weather-seal self-stick tape 3/8" wide, 3/16" thick (approx.) (see text)
■ 1	Grill cloth: 9.25" x 60" (approx.) (optional)
■ 4	Mounting feet

Materials/Parts Center Channel Speaker

The center channel speaker is a more conventional box design (11.5" x 16" x 8"). It is much easier to build and costs much less. The speaker selection was more arbitrary than for the buried tweeter design. Photos 3 and 4 show the basic design and construction method. A table saw is not required but it is helpful. Actual dimensions can be varied to some degree. Because the speaker has a four ohm impedance, a four-ohm resistor was added in series to increase the impedance to eight ohms. If your center channel amplifier can drive four ohms, then this resistor is not needed.

Some recordings provide good separation and others provide good realism. Generally, orchestral recordings exhibit good realism. This is especially true for choral works. Studio recordings generally provide better separation (obviously it is easier for them to control the crosstalk between channels). Often times, the music from a movie will provide excellent results. The CD, "I Am Sam" is such an example (V2 Records/New Line Cinema).

Conclusion

Sonic realism is possible, but there are three factors that must be addressed. The first is that consistent phase is a critical factor. There is also the requirement of a center channel. Lastly, the recording techniques can provide a significant variation to the quality of the realism. One does not

have to spend thousands of dollars for realistic stereo. However, one does

need to pay attention to the sonic details. **NV**

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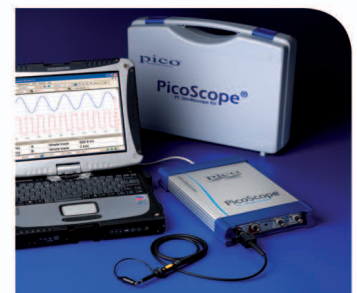
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IN THE SPOTLIGHT

Andrew Young and
Neal Greenberg.



An Interview with Neal Greenberg

by Marvin Mallon

This month's spotlight is on Schmartboard™, a California organization located in the city of Fremont, situated north of San Jose. The principal product of the company is a cleverly designed prototyping board. Although electronic componentry made a great leap forward in the 21st century, prototype technology lagged far behind. Hence, the creation and marketing of the Schmartboard.

Two friends joined forces to produce this new concept. Andrew Young, co-founder, President and CEO, began by founding Intellect Lab, an electronic engineering service firm and, prior to that, Shark Multimedia Inc. He holds a BS in Electrical Engineering from San Jose State University and an MS from Santa Clara University.

Schmartboard was spun off in 2005 from Intellect Lab where the concept of this high-tech prototyping board was invented in 2003. This privately owned corporation has five full-time employees in a manufacturing facility that they have outgrown. A search is underway for a bigger building to house and better serve their growth plans.

Andrew's partner at Schmartboard is Neal Greenberg. Neal also cofounded the company and serves now as Vice-President of Sales and Marketing. He is a graduate of William Rainey Harper College having obtained an AA degree in Applied Science. Additionally, he has a BS in Marketing from California Coast University.

In an interview with Neal, he responded to our questions about the present and future plans for the company.

Marvin: Neal, what are your most popular products and when were they introduced?

Neal: The SchmartBoard|ez™ family of products was released in September 2005 at the Demofall show. Demo is a show in which the most innovative products are launched. Previous products launched at Demo include Java 1.0, Tivo, and Palm. The SchmartBoard|ez is innovative because for the first time, anyone can hand solder SMT (Surface Mount Technology) parts. Whether it is a part with a tiny pitch such as 0.4 mm or has 200 legs, SchmartBoard|ez has made it possible for people to easily, quickly, and flawlessly hand solder the parts.

M: What gave rise to the creation of this line of products?

N: With increasing time-to-market issues and cost concerns in our fast moving world, we knew that there had to be a better way. We also realized that in the past, a prototyping board could save the engineer valuable time and money by allowing changes to be made quickly and inexpensively. But prototyping boards had not kept up with technology. Prototyping boards have existed for a long time, but as surface mount components have become smaller and smaller, these boards have not kept up with the technology and have not remained a practical tool for most applications.

M: Is there a newly developed product ready for release?

N: We have a new product called the Power SchmartModule that was released in mid-April. SchmartModules are functional circuits (such as RS-232) that one can add to a SchmartBoard circuit so that they don't have to "reinvent the wheel." The Power SchmartModule will allow one to add power in one of seven voltage options to a circuit. The suggested retail is \$15.

Equally exciting is a contest to be announced on June 1st. The Second Annual Schmartie Awards is a contest to create schematics with bills of material that include SchmartBoards. The first prize will be \$1,000. In addition, the winning circuit will be turned into an SchmartModule and the winner will receive a commission on every unit sold worldwide. *Nuts & Volts* and *SERVO Magazine* are our Media Sponsors.

M: Finally, what are the principal advantages of working with the Schmartboards?

N: As more and more components have gone from through hole to surface mount, great advances have been made in the ability to make smaller and more advanced electronic devices. The problem though is while circuit assembly of these parts for robots is easy, it has made hand soldering for prototypes and projects almost impossible. The SchmartBoard|ez has changed this. We can put a soldering iron in the hands of a 10 year old who has never even heard of a soldering iron ... in less than a minute the 10 year old will hand solder a 0.5 mm QFP (Quad Flat Pack) device as good as an experienced technician. SchmartBoard|ez has made it possible for everyone from a rocket scientist to the weekend hobbyist to hand solder SMT parts.

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Understanding Digital Buffer, Gate, and Logic IC Circuits

by Ray Marston

PART 3: NAND Gate and OR Gate Circuits

Ray describes practical digital NAND gate and OR gate logic ICs in this third installment of this five-part mini series.

Device	Type	Description
4011B	CMOS	Quad 2-input NAND gate
4093B	CMOS	Quad 2-input Schmitt NAND gate
74LS00	LS TTL	Quad 2-input NAND gate
74HC00	CMOS	Quad 2-input NAND gate
74LS132	LS TTL	Quad 2-input Schmitt NAND gate
74HC132	CMOS	Quad 2-input Schmitt NAND gate
74LS10	LS TTL	Triple 3-input NAND gate
4023B	CMOS	Triple 3-input NAND gate
74LS20	LSTTL	Dual 4-input NAND gate
4012B	CMOS	Dual 4-input NAND gate
74LS30	LS TTL	8-input NAND gate
4068B	CMOS	8-input NAND gate
74HC133	CMOS	13-input NAND gate

FIGURE 1. Thirteen popular NAND gate ICs.

The first two parts in this series explained modern TTL and CMOS logic gate basics and gave practical descriptions of some of the most popular digital buffer, inverter, and AND gate logic ICs that are available. This month, we'll expand on this basic theme and describes a

variety of popular NAND gate and OR gate ICs that are available from either your local supplier or from specialist dealers.

Practical NAND-Gate Digital IC Circuits

The output of a digital NAND gate goes low when all of its inputs (A and B, etc.) are high. Figure 1 lists basic details of 13 popular NAND-gate ICs; of these, the 74LS00, 74HC00, and 4011B (see Figures 2 and 3) are standard quad two-input types, and the 4093B, 74LS132, and 74HC132 (see Figures 4 and 5) are Schmitt quad two-input types. The 74LS10 and 4023B (see Figures 6 and 7) are triple three-input standard types; the 74LS20 and 4012B (see Figures 8 and 9) are dual four-input standard types; the 74LS30 and 4068B (see Figures 10 and 11) are eight-input standard types; and the 74HC133 is a 13-input standard type.

When using NAND gate ICs, each unwanted gate should be disabled by shorting all inputs together

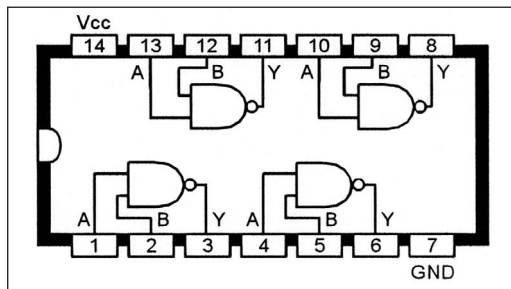


FIGURE 2. Functional diagram of the 74LS00 or 74HC00 quad two-input NAND gate IC.

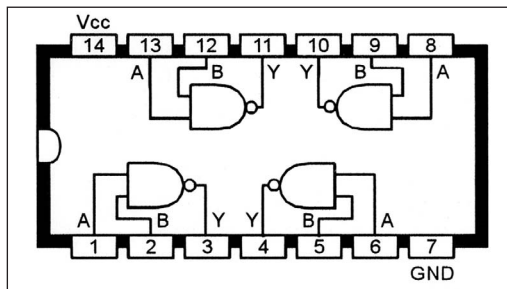


FIGURE 3. Functional diagram of the 4011B quad two-input NAND gate IC.

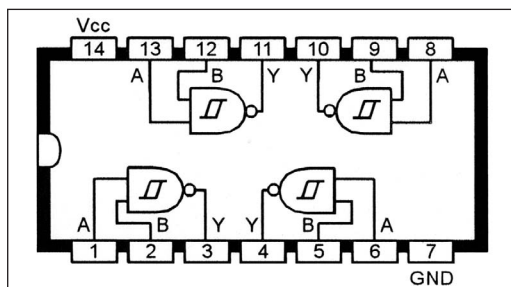


FIGURE 4. Functional diagram of the 4093B quad two-input Schmitt NAND gate IC.

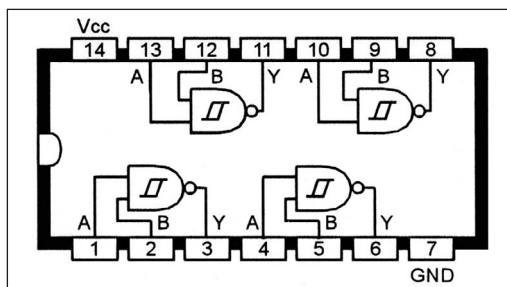


FIGURE 5. Functional diagram of the 74LS132 or 74HC132 quad two-input Schmitt NAND gate ICs.

and tying them to one of the IC's supply lines. In CMOS ICs, the shorted inputs can be wired directly to either supply line, but in TTL ICs the inputs must (to give minimum quiescent current consumption with good stability) be tied directly to the 0V rail, as shown in Figure 12.

Sometimes, when using NAND gate ICs, you may not want to use all of a gate's input terminals. In this case, the unwanted inputs can be disabled by either tying them high (directly in CMOS gates, or via a 1K resistor in TTL types) or by simply shorting them directly to a used input. Figure 13 shows examples of a three-input TTL NAND gate wired for use as a two-input type.

Note that the fan-in of a TTL NAND gate is an almost constant '1,' irrespective of the number of inputs used. Thus, CMOS or TTL NAND gates can be converted into simple inverters by simply shorting all of their inputs together. Figure 14 shows examples of TTL NAND gates used as inverters. Also note that NAND gates are fairly versatile elements, as demonstrated in Figure 15, which shows ways of using two-input elements to make a two-input or three-input AND gate or a three-input NAND gate.

Practical OR Gate IC Circuits

The output of an OR gate goes high when any of its inputs (A or B, etc.) go high. The simplest way to make an OR gate is via a number of diodes and a single

resistor, as shown (for example) in the three-input OR gate of Figure 16. The diode OR gate is reasonably fast, very cost-effective, and can readily be expanded to accept any number of

inputs by simply adding one more diode to the circuit for each new input.

Relatively few dedicated OR gate ICs are available. Figure 17 lists basic

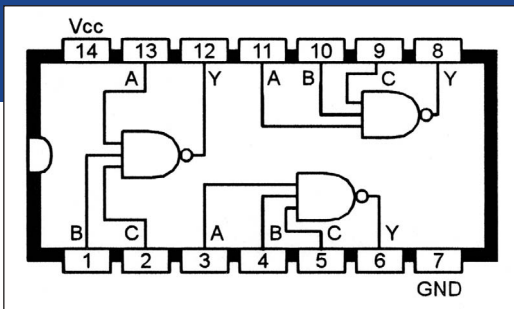


FIGURE 6. Functional diagram of the 74LS10 triple three-input NAND gate IC.

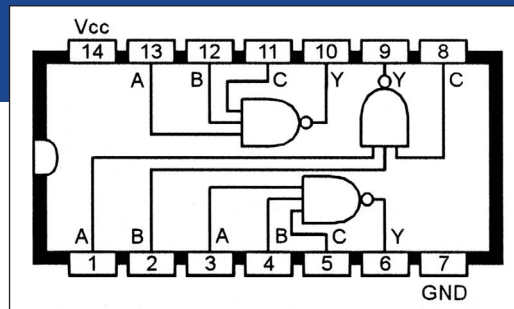


FIGURE 7. Functional diagram of the 4023B triple three-input NAND gate IC.

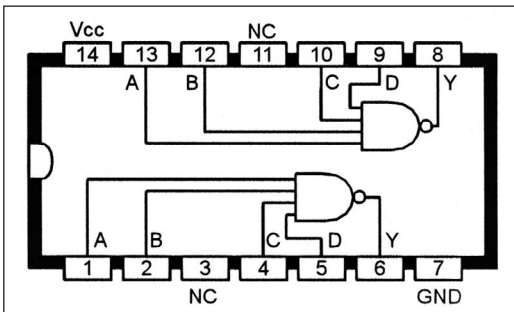


FIGURE 8. Functional diagram of the 74LS20 dual four-input NAND gate IC.

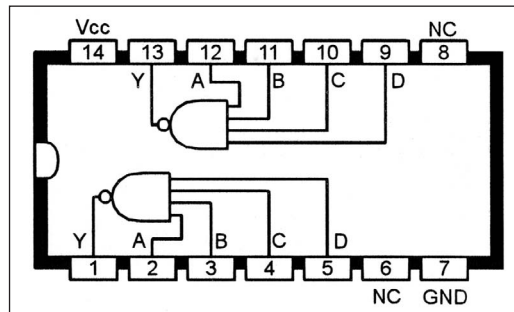


FIGURE 9. Functional diagram of the 4012B dual four-input NAND gate IC.

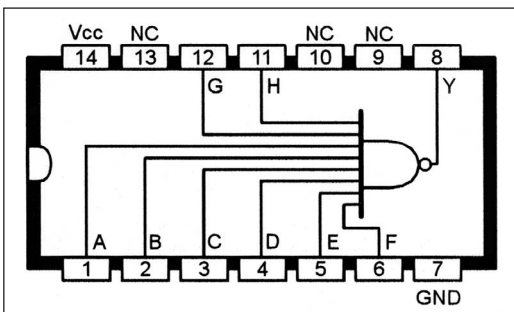


FIGURE 10. Functional diagram of the 74LS30 eight-input NAND gate IC.

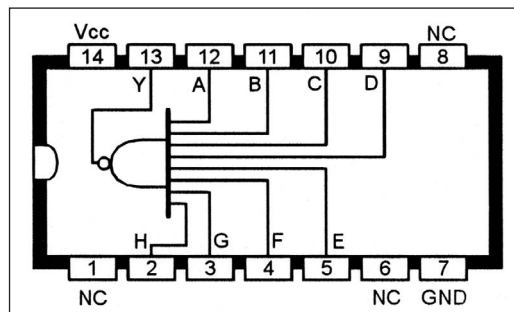


FIGURE 11. Functional diagram of the 4068B eight-input NAND gate IC.

FIGURE 12. Methods of disabling unwanted TTL NAND gates.

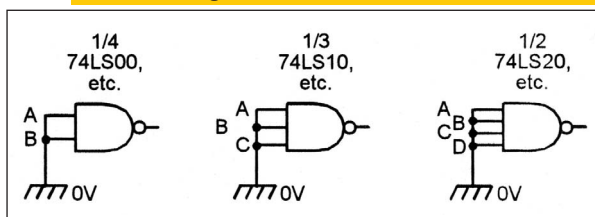


FIGURE 14. Methods of using TTL NAND gates as simple inverters.

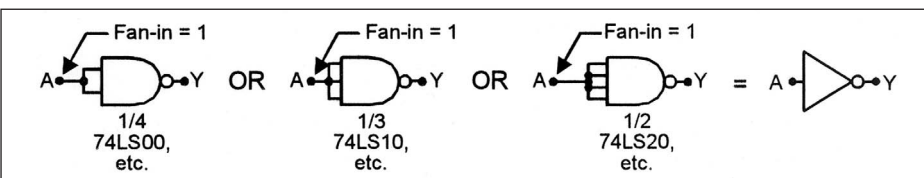
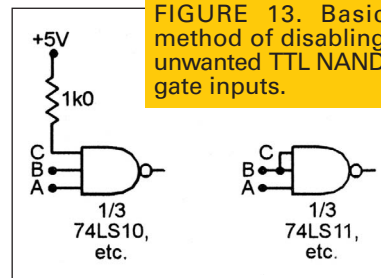


FIGURE 13. Basic method of disabling unwanted TTL NAND gate inputs.



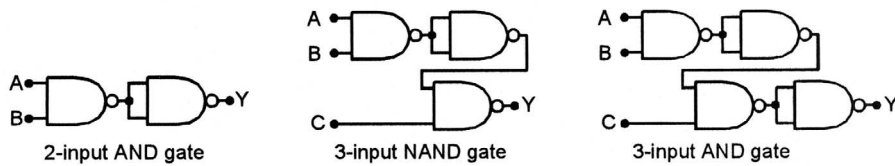


FIGURE 15. Ways of using two-input NAND gates to make various AND and NAND gates.

Figures 18 and 19) are quad two-input types; the 4075B and 74HC4075 (see Figure 20) are triple three-input types; and the 4072B (see Figure 21) is a dual four-input type.

When using OR gate ICs, each unwanted gate should be disabled by shorting all of its inputs together and tying them to one of the IC's supply lines. In CMOS ICs, the shorted inputs can be wired directly to either supply line, but in TTL ICs the inputs must (to give minimum quiescent current consumption with good stability) be tied high via a 1K resistor, as shown in Figure 22.

Note that the fan-in of a TTL NOR gate is directly proportional to the number of inputs used – at a fan-in rate of one per input – and that a TTL two-input OR gate can be made to act as a simple non-inverting buffer by either tying one input to ground or by tying both inputs together, as shown in Figure 23. Just make sure the buffer has a fan-in of one in the former case, and a fan-in of two in the latter. Also note that OR gates can be directly cascaded to make a compound OR gate with any desired number of inputs. Figure 24, for example, shows ways of cascading two-input OR gates to make OR gates with three, four, or five inputs, and Figure 25 shows a three-input OR element and a three-input diode OR gate cascaded to make a compound five-input OR gate.

ways of cascading two-input elements to make OR gates with three, four, or five inputs, and Figure 25 shows a three-input OR element and a three-input diode OR gate cascaded to make a compound five-input OR gate.

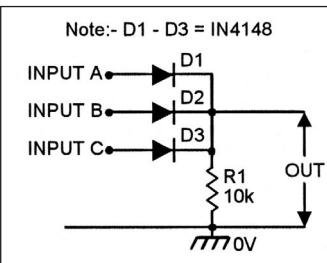


FIGURE 16. Simple three input diode OR gate.

Device	Type	Description
74LS32	LS TTL	Quad 2-input OR gate
74HC32	CMOS	Quad 2-input OR gate
4071B	CMOS	Quad 2-input OR gate
4075B	CMOS	Triple 3-input OR gate
74HC4075	CMOS	Triple 3-input OR gate
4072B	CMOS	Dual 4-input OR gate

FIGURE 17. Six popular OR gate ICs.

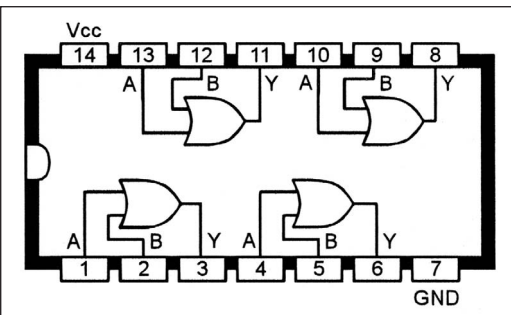


FIGURE 18. Functional diagram of the 74LS32 or 74HC32 quad two-input OR gate IC.

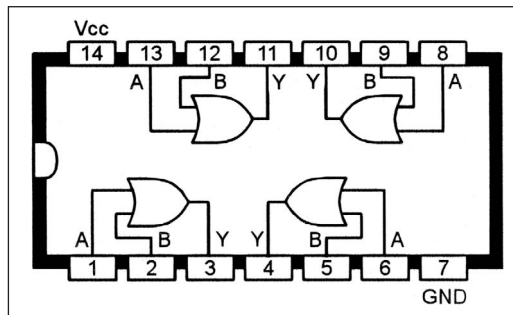


FIGURE 19. Functional diagram of the 4071B quad two-input OR gate IC.

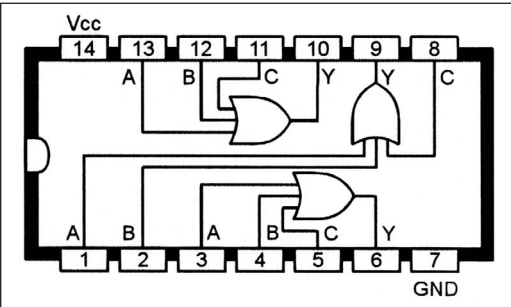


FIGURE 20. Functional diagram of the 4075B or 74HC4075 triple three-input OR gate IC.

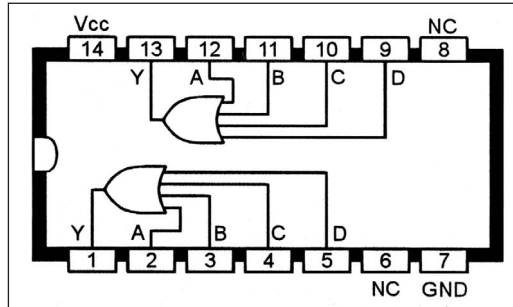


FIGURE 21. Functional diagram of the 4072B dual four-input OR gate IC.

FIGURE 22. Method of disabling a TTL OR gate.

details of the six most popular OR gate ICs: the 74LS32, 74HC32, and 4071B (see

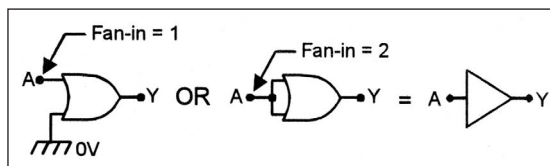
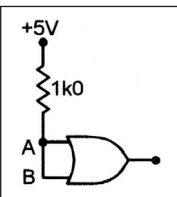


FIGURE 23. Ways of using a TTL OR gate as a simple buffer.

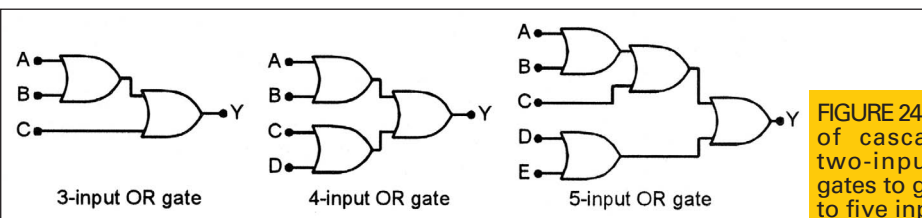
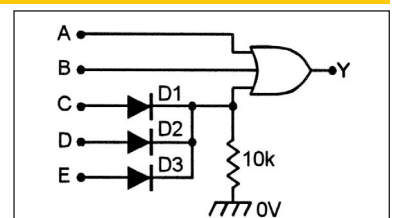


FIGURE 24. Ways of cascading two-input OR gates to get up to five inputs.



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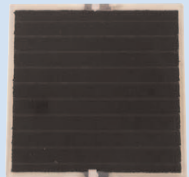
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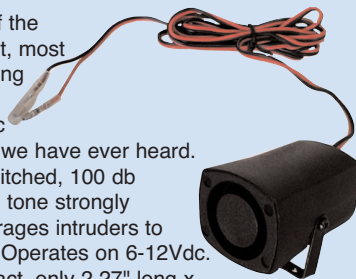
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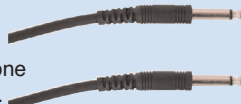
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Note: We have been told recently that in order to use this transmitter as a primary control, it is necessary to use a micro controller module to split and amplify the received signal into six individual channels.

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Creating an EXERGAME With the HYDRA GAME SYSTEM

by Bryan Bergeron

EXERGAMES, typified by *Dance Dance Revolution* and the more recent *Wii Sports* compilation for the Nintendo Wii, encourage whole body movement over mere thumb flexing. Whether players intend to shave a few extra pounds or to simply interact with a more engaging interface, exergames rely on non-traditional input devices and technologies for gameplay.

Given the popularity of exergames and the success of the Wii interface, when I was asked to review the Hydra Game System, I couldn't resist exploring the feasibility of developing an exergame. This article describes the development of a simple exergame using the latest addition to the Parallax line of microcontrollers and a popular dual-axis accelerometer.

Exergame Design

The design of an exergame, like that of other serious games, starts with the creation of a game design document that addresses a relevant subset of the issues outlined in Table 1. For example, every exergame should incorporate

FIGURE 1. Wobble board, side (left) and top (right) views.

fun elements, such as some form of escalating challenge, but not all exergames require music. Of key importance in an exergame design document is identifying the skill set that should be developed in players. This skill set drives the visual, physical, and logical components of the game design.

A useful construct in designing most exergames is mapping skills to gameplay and a reward system or scoring. For example, an exergame could replicate the rehabilitation regimen required by a player with an ankle injury. If rehabilitation involves

predominantly lateral or side-to-side ankle exercises, then a game that incorporates left and right ankle flexion in gameplay may be appropriate. Moreover, just as an elastic band or other tool can be used to achieve a variety of rehabilitation goals, a single exergame can often be used to enhance a variety of skills. A game that emphasizes ankle movement could be used to improve the player's balance and body awareness, for example.

The exergame considered here is designed to encourage use of a common wobble board. As shown in Figure 1, a wobble board is simply a



EXERGAME DESIGN ELEMENTS

Setting	Logic
Characters	Equipment
Effectors	Cameras
Game Flow	Objectives
Screens & Menus	Introductory Material
Controls	Gameplay
Options	Closing Material
Sounds & Music Environment	Scoring
Map	Skill Set
Fun Elements	Media Assets

TABLE 1. Basic exergame design elements. Every element may not be applicable to a given game.

FIGURE 2. Game screen shots showing wobble board-controlled dot off target (left) and on target (right).

plastic or wooden disc, typically 18 inches in diameter. A dome over a pivot point in the center of the bottom side allows 15 to 20 degrees of tilt. OPTP is one of several vendors that offers affordable models starting at about \$40 (www.optp.com).

Physical therapists and sports trainers use balance boards with their clients to rehabilitate ankle injuries, enhance range of motion, and for general motor skill training. Many runners and martial artists incorporate wobble boards in their training programs to increase flexibility and reduce incidence of injury. The downside of working with a wobble board is that there is no immediate feedback and the routines quickly become boring — hence the motivation for an exergame.

The on-screen view of the wobble board-controlled exergame is shown in Figure 2. After a series of count-down screens, the player is presented with a constantly moving bull's-eye target. While standing on the wobble board, the player attempts to adjust the tilt of the board so that the white dot constantly tracks the center of the bull's-eye. The goal of gameplay is to track the bull's-eye target as long as possible within 100 seconds. Contact time translates directly to score.

To move the dot up on the TV display, the player tilts the wobble board forward by pressing her toes down while simultaneously adjusting her body to maintain balance. Similarly, moving the dot to the left involves the player shifting her body weight, pressing her left leg down, and flexing her ankles to the right. Intermediate players can stand with their feet together. Advanced players can stand on one foot while holding their free knee to their chest or performing a similarly challenging maneuver. Based on personal use and feedback from several users, the game succeeds in transforming a typically boring series of exercises into a fun and slightly addictive activity.

The following sections describe the Hydra Game System, including the hardware and software, the characteristics of the Memsic 2125 accelerome-



FIGURE 3. Hydra board with EEPROM card.

ter, and the software and hardware required to interface the accelerometer to the Hydra.

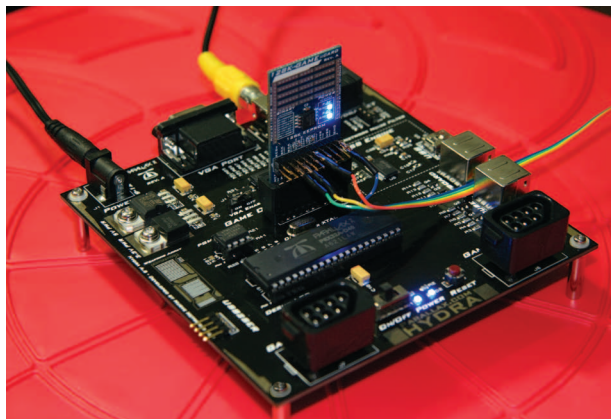
Hydra Game System

The Hydra Game System is aptly named, in that it isn't simply another microcontroller board, but is a complete system for game development. In addition to the Hydra board and peripherals, the system includes a CD-ROM filled with software and an 800+ page book that provides an integrated explanation of the hardware environment in the context of classic or retro game development.

Working with the Hydra board (see Figure 3) and library of games, game engines, and demos — including titles inspired by *Breakout*, *PacMan*, *Lock N Chase*, *Q-bert*, and *Centipede* — is like taking a step back in time to the days of the Atari and Commodore-64. Although VGA is supported, most of the demos are written to composite NTSC video, which accounts for the low resolution, retro look of the exergame shown in Figure 2.

Hardware

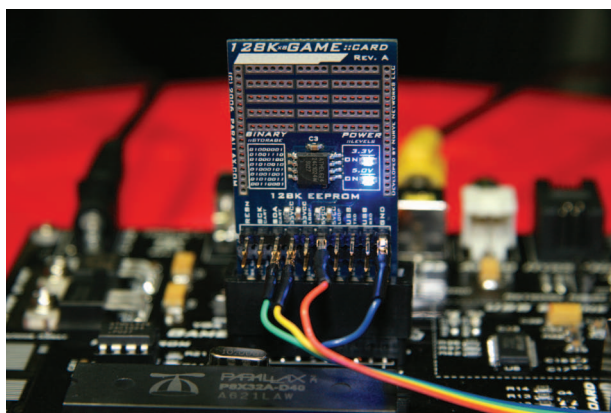
The main Hydra board is populated with an eight-core Propeller chip clocked at 80 MHz, a 128 KB EEPROM, and a 10 MHz crystal. All three of these core compo-



nents are socketed for future upgrades and experimentation. The Hydra also sports a game card expansion port near the center of the board, and ports for RCA audio and video out, VGA out, PS/2 mouse and keyboard, RJ-11 serial network, 9 VDC power in, mini-USB, four-pin USB2USER, and a pair of Nintendo NES gamepads.

The Hydra Game System includes a blank experimentation card and a 128K EEPROM card, either of which can be plugged in to the game card expansion port. Additional cards can be purchased from Parallax; 3V and 5V power, eight I/O ports, serial network, USB, and EEPROM lines are available from the 20-pin game card expansion port, and on the EEPROM and experimental card solder pads. To facilitate

FIGURE 4. 128K EEPROM card with 2 x 10 header pins soldered to the I/O pads.



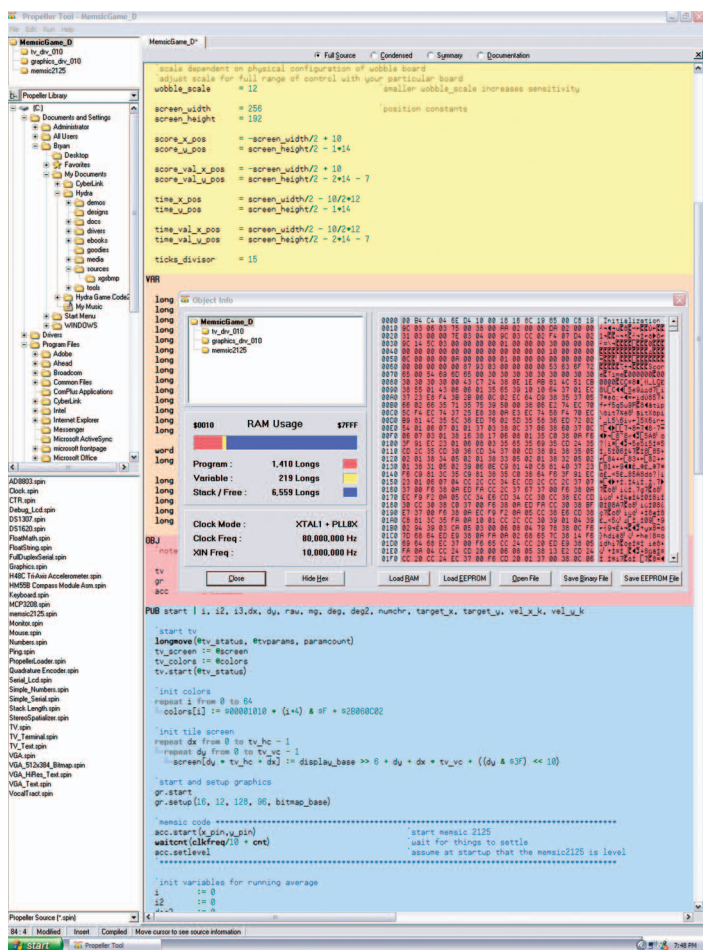


FIGURE 5. Parallax Propeller IDE.

A feature of the IDE is the option to either quickly load a program into RAM during development or load the program into onboard or expansion card EEPROM. The later operation requires a few more seconds. When the 128K EEPROM expansion card is inserted, the onboard EEPROM is automatically disconnected.

Following the spirit of the SPIN language, the exergame was developed in about 200 lines of high-level SPIN — much of which was borrowed from or inspired by the demos on the CD-ROM. The code is available for download from the *Nuts & Volts* website (www.nutsvolts.com). The objects — akin to include files in C — used in the exergame are TV and graphics drivers from the Hydra Game System and the Memsic 2125 driver from the Parallax library. Note that unlike the Parallax objects, the sources included on the Hydra CD-ROM may not be freely distributed.

Because SPIN uses white spaces to indicate block levels, it's a good idea to use the IDE's highlight function (Control-I) that shows block relationships. As an example of how white space is used within the IDE, consider the following SPIN code from the exergame:

```
if || (i_squared - t_squared) < 550 'absolute value
if (timeRemaining > 0) 'time variable
gr.text(-120,-80,string("Score!")) 'print "Score!"
totalPoints := totalPoints + 1 'add points
```

Although the IDE is very sophisticated for a microcontroller system, version 1.05.2 lacks a true debugger. There is an on-board LED and it is possible to write values to the video out port, but both approaches are limited. Using video consumes cycles and precious RAM. A traditional text-based debugger — such as the one available for the BASIC Stamp microcontrollers — would be more useful.

You'll also find a small TV with composite video and audio input — or a computer monitor with a composite video input port — necessary for efficient game development. If you don't have a dual monitor setup on your PC, Parallax offers a nice 2.5" LCD monitor that supports composite video and audio.

Wobble Board Interface

There are several ways to interface a wobble board to the Hydra to create an exergame. The simplest is to mount four mercury switches on the wobble board oriented such that one switch is closed with the board tilted forward, back, right, and left. Wire each mercury switch in parallel with the appropriate button on the NES game controller and the wobble board becomes a proxy for the controller pad.

Unfortunately, mercury switches are inherently limited because of their sluggish response time and binary output. Finer resolution in direction and degree of tilt requires more switches and I/O lines. A more flexible approach is to use an accelerometer that supports continuous sensing of tilt.

The two obvious options for this project are the Memsic 2125 dual-axis accelerometer and the Hitachi H48C tri-axis accelerometer. Both units are supported by Parallax, and driver objects for each sensor can be freely downloaded from the Parallax site. Because only two-axis tilt is required, the less expensive Memsic 2125 is used here.

experimentation, I soldered 2 x 10 header pins to the 3 mm spacing, through-hole solder pads, as shown in Figure 4.

Because the I/O lines on the expansion bus are shared by the VGA connector, VGA output must be disabled to use the expansion port I/O. In addition to the eight I/O lines on the expansion port, the serial network transmit and receive lines routed to the RJ-11 jack are available for I/O.

Additional components of the Hydra Game System include a compact 9 VDC power brick, USB and RCA cables, a miniature keyboard, travel mouse, and a NES-compatible gamepad. The mouse and gamepad are useful for playing games, and the small but useable keyboard is primarily used for programming the Hydra without a PC using Hydra Basic. Although a rudimentary operating system may be downloaded from the online forums to facilitate use of Hydra Basic, the utility of the language is limited by the 32K RAM available on the Propeller chip.

Propeller IDE

My sense of nostalgia evaporated as soon as I started working with the numerous examples provided on the CD-ROM. Instead of linear Basic, FORTH, or assembler, games on the Hydra are written using high-level SPIN and, for the technically endowed, low-level assembler. SPIN is unusual in that it borrows somewhat from object oriented languages and supports multiple cores. The multi-core paradigm takes some getting used to, as does the colorful Parallax Propeller IDE, shown in Figure 5. The MS Windows-based IDE can be freely downloaded from the Parallax site.

FIGURE 6. Calculation of acceleration (A) for each axis of the Memsic 2125.

The Memsic 2125 thermal accelerometer is an example of a micro electro-mechanical machine system (MEMS) based on IC manufacturing techniques (hence the name MEMSIC). In operation, a heater within the Memsic 2125 warms a bubble of gas that moves in response to gravity and acceleration of the device. Thermopiles near the periphery of the bubble sense identical temperatures when the accelerometer is level and different temperatures if the device is tilted.

Temperature differences detected by the thermopiles are converted into pulses by the onboard electronics according to the relationship illustrated in Figure 6. Acceleration at earth normal gravity (9.8 m/s²) is considered 0, and the update frequency is approximately 100 Hz at room temperature.

The angle of tilt is calculated with elementary trigonometry, given the accelerometer signals from the x and y axes. For example, if the duty cycles of the x- and y-axis signals increase equally, then the angle of tilt is equidistant between the two positive x and y axes, or 45 degrees. The amount of tilt in this direction is a function of the magnitude of the positive shift in duty cycle, as described in Figure 6. Fortunately, the low-level magnitude and direction calculations are handled by the Memsic 2125 driver from Parallax.

Figure 7 shows the dual axis recording of the Memsic 2125 used in my exergame. Note the clean square wave output and a frequency of just over 100 Hz. There is an obvious difference between the x-axis (top) and y-axis (bottom) duty cycles. According to the formula in Figure 6, the accelerations along each axis are:

$$\begin{aligned} A_x &= (T1/T2 - 0.5) / 0.125 \\ A_x &= (4.7\text{ms}/10\text{ms} - 0.5) / 0.125 \\ A_x &= -0.03 / 0.125 \\ A_x &= -0.24g \end{aligned}$$

$$\begin{aligned} A_y &= (T1/T2 - 0.5) / 0.125 \\ A_y &= (5.2\text{ms}/10\text{ms} - 0.5) / 0.125 \\ A_y &= 0.2 / 0.125 \\ A_y &= 0.16g \end{aligned}$$

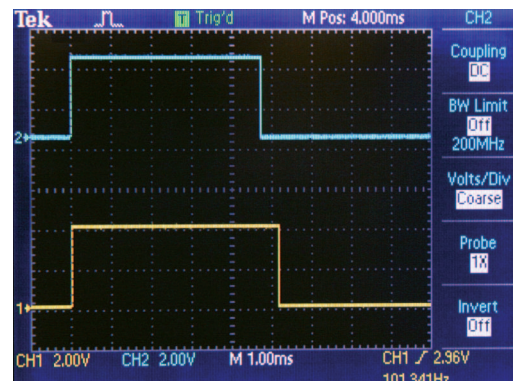
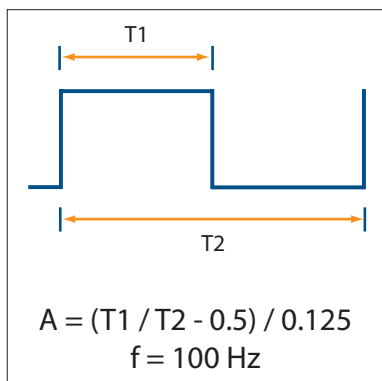


FIGURE 7. X- and y-axis output of a Memsic 2125 showing different x and y duty cycles.

These calculations indicate negative acceleration — and therefore tilt — along the x-axis and positive acceleration along the y-axis of the accelerometer.

Connecting the Memsic 2125 to the game card on the Hydra requires four lines. As shown in Figure 8, the accelerometer requires 5 VDC at 4 mA, ground, and access to two I/O ports on the Hydra. I used 1/8 watt, 220 ohm resistors on the x- and y-axis output pins of the accelerometer and connected these to I/O pins 6 and 7 on the Hydra EEPROM card, respectively.

The specifics of mounting a Memsic 2125 on a wobble board depend on the design of your particular board. The mount shown in Figures 9 and 10 are specific to the OPTP wobble board. Although not visible in Figure 9, the Memsic 2125 is inserted into an eight-pin socket so that the sensor can be used in other projects. Figure 10 shows the perf board glued in place, along with the four-pin 0.10" connector on the cable to the 128K EEPROM card on the Hydra.

Game Coding

The core algorithm in the exergame compares the distance between the origin at the center of the screen to the dynamic bull's-eye and the wobble board-controlled dot. If the distances — the hypotenuses of the triangle incorporating the bull's-eye and the triangle incorporating the dot — are not significantly different, then the assumption is that the dot is on target. As in the following SPIN

FIGURE 8. Wiring of Memsic 2125 to the Hydra EEPROM card.

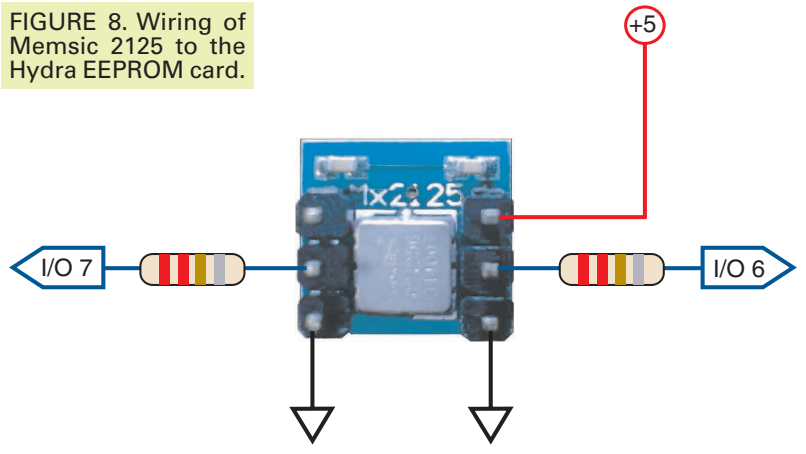
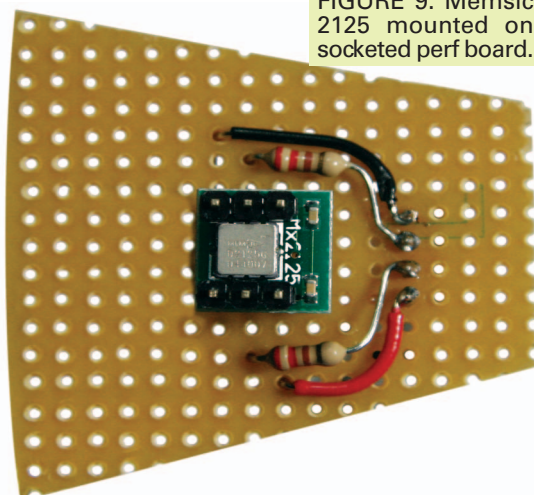


FIGURE 9. Memsic 2125 mounted on socketed perf board.



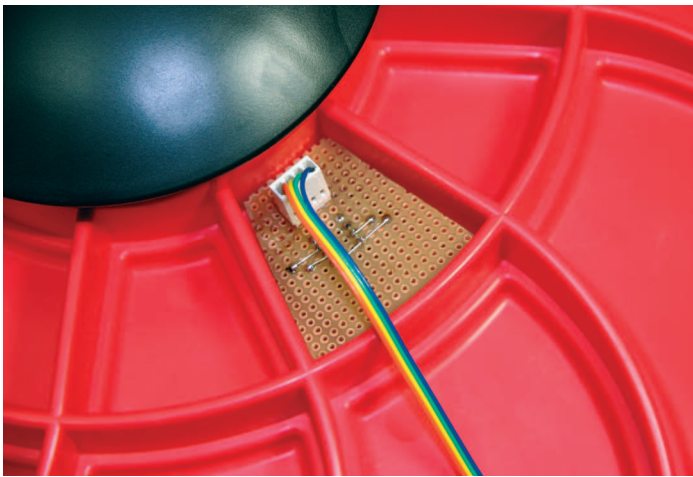


FIGURE 10. Memsic mounted in base of an OPTP wobble board.

code, the score is updated and the message "Score!" appears on the screen when the dot tracks the center of the target.

```
t_squared := (target_x * target_x) + (target_y *
target_y)
i_squared := i*i

if || (i_squared - t_squared) < 550
if (timeRemaining > 0)
gr.text(-120,-80,string("Score!"))
totalPoints := totalPoints +1
```

The downside of this simple test for target and dot overlap is that there are multiple possible dot locations that will result in points. However, in practice, this simplification works well. A more complete and complex approach is to use a sine lookup table and compute the single point on the screen where target and player-controlled dot overlap in real time. Readers interested in following this approach can view several examples in the text accompanying the system.

The Memsic 2125, like every sensor, is imperfect. In addition to device-to-device differences in response and settling time, output from a stationary accelerometer varies randomly over time.

Figure 11 shows the single-axis output of a Memsic 2125 mounted horizontally on a stable surface. The 5,000 consecutive readings were collected at 10 Hz using a BASIC Stamp. The output of the accelerometer is Gaussian, with a mean of 4,908 microseconds and a standard deviation of two microseconds.

This output variability is significant in the game, in that the position of the white dot visibly jitters even when the wobble board is held stationary. I handle this jitter in accelerometer output with two simple filter routines written in SPIN. They take the form:

```
if || (acc2 - acc1) > 10 'compare acceleration values
acc1 := acc2 'update values if different
acc2 := memsic_output 'update acceleration value
acc1 := (acc + acc2)/2 'average acceleration
```

The filters are based on value differences instead of consecutive readings from the Memsic 2125 because the Propeller is operating at a significantly higher frequency than the accelerometer.

A final note regarding coding the Hydra is that this exergame relies on the Memsic 2125 object supplied by Parallax. This object or driver includes a self-calibration routine at startup that assumes the accelerometer is level. As such, the wobble board must be positioned close to horizontal at startup.

From Here

The exergame described here is a mere hint of what can be accomplished with the Hydra Game System. Consider adding a colorful background from the extensive library of image files on the CD-ROM that accompanies the system. Sound effects are another obvious addition to the exergame. More importantly, the wobble board interface can be used with very little modification on many of the sample games on the Hydra CD-ROM. Imagine playing a game similar to Break Out using a wobble board instead of a controller pad.

According to Andre' LaMothe, developer of the Hydra and author of the text included with the system, a 512K expansion card is in production. The card will enable development of games with bitmapped graphics, more media, and, in general, greater complexity. Be sure to visit the forums on Parallax and XGameStation for any software updates and hardware extensions. **NV**

RESOURCES

Hydra Game Development Kit, Memsic 2125 accelerometer, and software objects available from Parallax.
www.parallax.com

Hydra Developer's Forum.
[Forums.parallax.com/forums](http://forums.parallax.com/forums)

XGameStation.
Andre' LaMothe's website for the Hydra, documentation, and forums.

Bergeron, B., *Developing Serious Games*. 2006: Thompson.

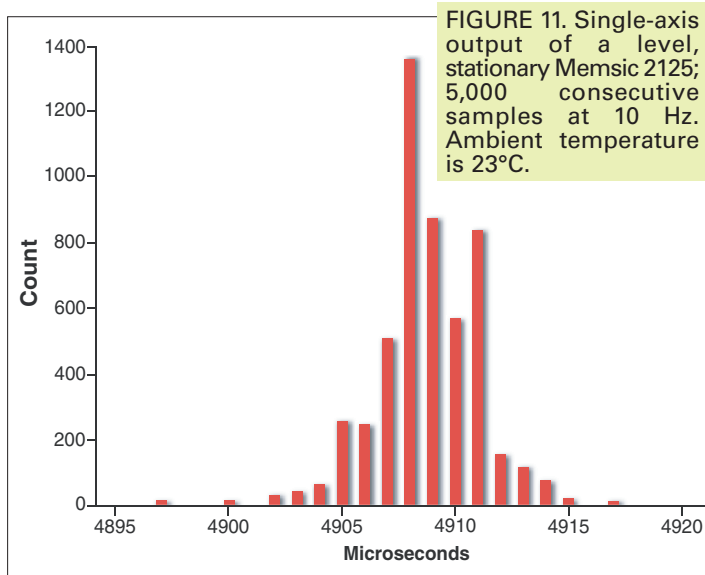


FIGURE 11. Single-axis output of a level, stationary Memsic 2125; 5,000 consecutive samples at 10 Hz. Ambient temperature is 23°C.

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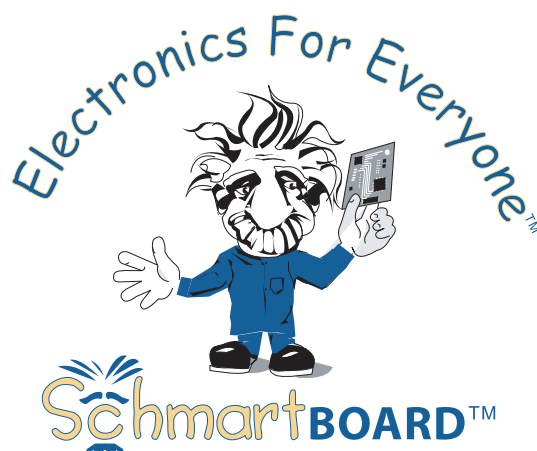


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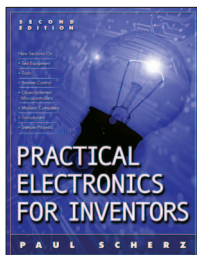
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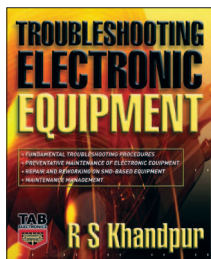
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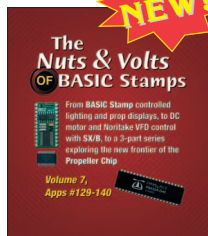
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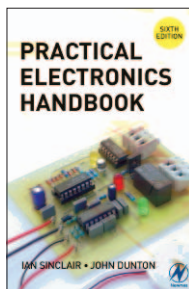


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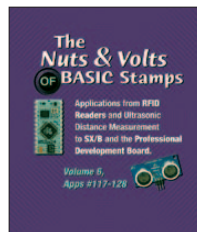
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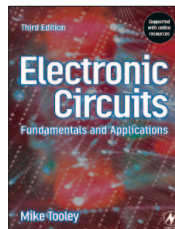
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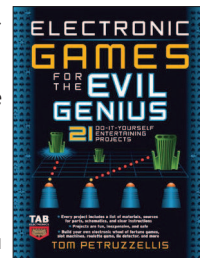
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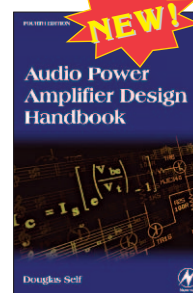
by Thomas Petruzzellis

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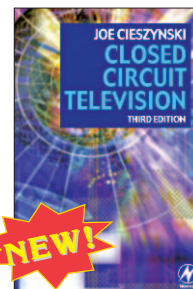
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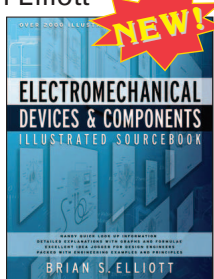
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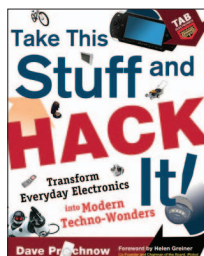


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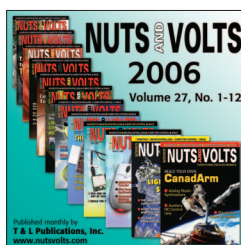
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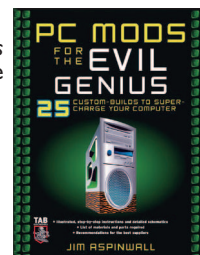


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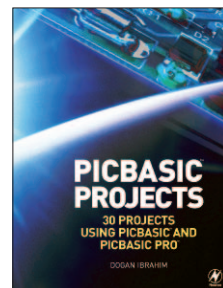


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by Jack Smith

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■ BY LOUIS E. FRENZEL W5LEF

FIBER OPTICS — The Invisible Communications Network You Use Every Day

THE WORLD HAS BEEN REWIRED MANY TIMES over the decades. Telegraph and telephone wiring came first. Then electrical power. (Yes, electrical power wiring actually came *after* the telegraph and telephone wiring. Doesn't seem right does it?) Shortly after that came cable TV wiring. Computer network wiring was next. Then fiber optic cable. There has been some overlap of those, of course, but that is the general sequence.

Today, there is actually a fiber optic cable glut. Miles and miles of it were laid in the early Internet boom days of 1998-2002, then the crash. Lots of that cable is still unused or as they say in the industry, it is "dark" fiber. With booming Internet activity going on today and the push toward TV over the Internet, lots of that fiber is being brought out of the darkness and even more new fiber is being laid for special applications.

Fiber optic communications systems are not something we think of every day even though we all use them. Don't think so? Consider this. When you make a long distance call, the fiber network is used. In fact, in making any phone call today — wired or wireless — somewhere in the telephone system your call is being carried at least part way by light waves over fiber. Do you have cable TV? (Over 80% of the US population does so you probably do, too.) Most cable TV systems are what

we call hybrid fiber cable (HFC) systems meaning that a main fiber optic backbone cable carries the TV signals to a box in your neighborhood where the connection continues from that box to your home over RG-6/U 75-ohm coax. If you use email or the Internet, you use fiber because the backbone of the Internet is fiber. And most of that fiber is buried and invisible.

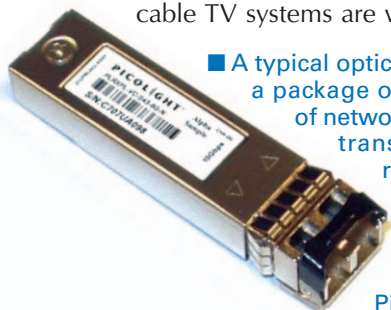
Recently, I attended the Optical Fiber Conference (OFC) in Anaheim, CA. I have not been to that conference in a few years as the early 2000's were really rough on the fiber industry. When the Internet bubble burst in 2001, the fiber industry essentially collapsed. It did not go away, of course, but little new equipment was sold, lots of R & D was abandoned or put on hold, start-up companies folded, and lots of other companies were bought and/or merged. All that consolidation turned out to be good and business has emerged even stronger today. The OFC

was booming again this year as the industry renews its growth cycle. Here is a look at some of the latest trends and developments in this field which affect us all, even if you think it doesn't.

REMEMBER HOW IT WORKS

Fiber optic communications is the transmission of light over a glass or plastic fiber cable. The light is generated by a laser in most cases, but in some smaller, slower networks an LED is used. The light is infrared (IR) so you cannot see it as it is lower in frequency than red light. The light color or frequency is usually expressed in wavelengths (λ) and that is measured in nanometers (nm). A nanometer is one billionth of a meter. IR light extends from about 700 to 1,600 nm. The most common IR operational wavelengths are 780, 850, 1,310, 1,490, and 1,550 nm. The 780 nm wavelength is the common TV remote control frequency while 1550 nm is the main long distance high speed operating wavelength.

In any case, since most signals are digital data today, the binary signals simply modulate the light by turning the laser light off and on creating pulses. This is called on-off keying (OOK) or amplitude shift keying



■ A typical optical transceiver or transponder, about the size of a package of gum. Mounts on the printed circuit boards of networking equipment like routers. Contains the laser transmitter and photo diode receiver and all the related circuitry to perform optical to electrical conversions and vice versa. This one is called a small form factor pluggable (SFP+) for short range (SR). It uses a 850 nm laser and operates at 10 Gb/s. Photo courtesy of Picolight (now JDSR).

(ASK). The light pulses travel down the fiber and eventually encounter a photo diode at the receiver that converts the light back into a binary signal.

Data in the long distance and Internet back bones are usually sent with a protocol standard known as the Synchronous Optical Network or Sonet. What it does is package data into blocks or frames of 810 bytes of data and send it at one of several standard data rates; the slowest is 51.84 Mb/s and the fastest is 39.812 Gb/s. Most data exchange is done at the 2.488 and 9.953 Gb/s rates. See Table 1 for the Sonet standard rates.

Sonet networks are either point-to-point or in rings. The long haul networks are known as wide area networks (WANs). When Sonet is used in smaller city or town rings, it is called a metropolitan area network (MAN).

Ethernet — the local area networking (LAN) standard — now sends data over fiber (and copper) LANs at 1 Gb/s and 10 Gb/s. Data is by packets rather than synchronous frames so the format is less complex. High speed Ethernet is also being more widely used in MANs and in some cases, WANs like Sonet. The IEEE (Institute of Electrical and Electronics Engineers), who standardizes Ethernet, is working on a 100 Gb/s standard for long haul fiber networks.

FASTER AND FARTHER

In the computer, electronics, and communications fields, the ultimate and on-going goal is to make everything go faster and at a longer distance. The same is true in fiber optics. For years, the average long distance data rate over the backbone was 2.5 Gb/s (actually 2.488 Gb/s Sonet rate). Today, that has been increased to an average of 10 Gb/s. Most long distance calls and virtually all Internet messages go at that 10 Gb/s rate through the main routers in the system. The distance is roughly a maximum of several hundred kilometers before the light signals get too weak. They then need to be converted back to electrical signals where they are amplified, reshaped, and otherwise rejuvenated before being converted back to light and sent on their way.

Now the push is on to boost data rates and extend the range of the light

signals. Before the technology crash in 2001, there was an effort to boost the speed to 40 Gb/s (39.812 Gb/s Sonet rate). That work has now been renewed and there are lots of new products to support that data rate. Network providers are beginning to offer services at that speed. Verizon recently announced that some of their network segments in the northeast US have already been bumped up to the 40 Gb/s rate. And work is on the way to move that up to 100 Gb/s.

Besides the IEEE effort to build a 100 Gb/s Ethernet, other efforts are under way to boost the data rate to 100 Gb/s and beyond. Some of these are Sonet type systems while others are proprietary, but progress is being made. One of the easiest ways to get to 100 Gb/s over a single fiber is to use what is called dense wavelength division multiplexing (DWDM). This is a technique where a very high speed data stream is divided up into many slower streams. These streams are then transmitted simultaneously down the same fiber, but with each stream modulating a different light wavelength. The different “colors” of light travel down the fiber together and are separated out by filters at the receiver where they are then recombined back into the fast single stream.

Most of the first 100 Gb/s systems are using DWDM. But single wavelength 100 Gb/s is tough. One of the main reasons is that glass fiber greatly attenuates and distorts the light. These problems are called polarization mode distortion (PMD) and chromatic dispersion. New types of fiber help to mitigate the problems but mostly the problems are dealt with by an equalization technique implemented at the receiver. The signals are predistorted in a special way and the receiver corrects for them using fast digital signal processing techniques.

Another solution lies in using different modulation methods. The standard OOK or ASK is being replaced by more sophisticated modulation techniques like differential phase shift keying (DPSK) and differential quadrature phase shift keying (DQPSK). An old telephone system modulation method called duobinary has also been applied. All of these help overcome the attenuation and distortion allowing

TABLE 1. Sonet Data Standards and Rates

STS means synchronous transport signal and OC means optical carrier.

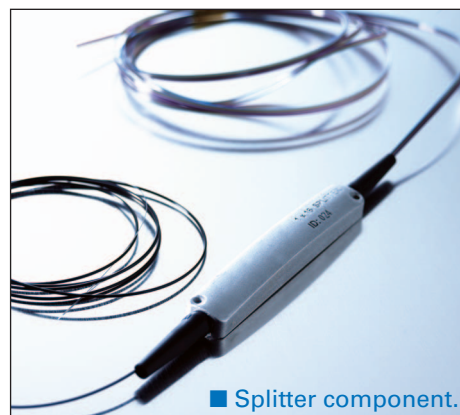
Sonet Level	Data Rate
STS-1/OC-1	51.84 Mb/s
STS-3/OC-3	155.52 Mb/s
STS-12/OC-12	622.08 Mb/s
STS-48/OC-48	2.488 Gb/s
STS-192/OC-192	9.953 Gb/s
STS-768/OC-768	39.812 Gb/s

faster data rates over longer distances.

There are lots of demo 100+ Gb/s systems. It will be a few more years before we see standards and equipment for those rates, but they are on the way. Why? Because of the greater load the Internet carries with the ever-increasing music downloads and the forthcoming Internet video. Companies will begin offering movies-on-demand or video-on-demand, as well as Internet protocol television (IPTV) that is designed to compete with the cable TV companies. The current Internet structure and bandwidth can handle some video now, but it will eventually be overwhelmed if video becomes popular on the Internet. The new 100+ Gb/s technology is on the way to solve this problem.

PASSIVE OPTICAL NETWORKS

Another hot optical topic today is the PON. Passive Optical Networks (PONs) are fiber optical networks designed so they do not use an active repeater or other equipment between the source central office and a home or business. Right now, most individuals



■ Splitter component.

and businesses get their Internet service via the cable TV system or the phone company's DSL lines. While both are fast, they are running out of steam, especially DSL. The ideal high speed service is fiber but it is more expensive at the moment. The ultimate goal is to run fiber to the home (FTTH) and use it to supply fast Internet access, phone service via voice over IP, and IPTV.

PONs make this possible because they are fast and reasonably inexpensive

due to their totally passive nature. For long haul fiber networks, the signals must be converted from optical to electrical and back to optical (OEO) to rejuvenate them in case of fiber loss and/or distortion. Such OEO repeaters are expensive. By eliminating them and just running the cables only, costs are cut dramatically making PONs a viable alternative to current methods like DSL and cable TV.

Asia (Japan and Korea, particularly) and some parts of Europe already

use EPON, a system based on the Ethernet standard. Data is transmitted at 1 Gb/s downstream over the fiber to the home on 1,490 nm where it encounters splitters that divide the optical signal and send it off to multiple homes or businesses. A splitter is just a passive light divider with no electronics. Splitters are available to divide the signal by a ratio of 1:4, 1:8, 1:16, 1:32, or 1:64. A splitter is also a combiner where it can take multiple light signals, add them together, and send the combination back to a central office. The upstream data rate is also 1 Gb/s, but it rides on a 1,310 nm wavelength.

In the US, Verizon has initiated its FiOS system using a PON in some parts of the country and selling the service as the faster alternative to cable TV and DSL. AT&T is also testing a similar system for IPTV. Fiber is a bit more expensive, but the basic data rates are in the 30 to 50 Mb/s; many times faster than conventional services. It can easily handle multiple HDTV channels, as well as VoIP phone service and Internet access. Several million homes already use it and more are being rolled out over the coming years.

The technology is referred to as GPON or Gigabit PON. The basic downstream data rate is 2.488 Gb/s on 1,490 nm with a fast 1.244 Gb/s upstream rate on 1,310 nm. A separate downstream wavelength of 1,550 nm is reserved for TV. While each customer does not get the full 2.488 Gb/s speed, the system divides the fast stream among the customers who are served by passive fiber and splitters.

Fiber is widely used in 1 Gb/s and 10 Gb/s Ethernet LANs and in Fibre Channel — a type of network widely used in storage area networks, large arrays of hard disk storage systems. The fiber provides 1, 2, 4, 8, or 10 Gb/s of speed so that servers can access data on the disk drives fast.

As prices continue to drop and the pressure continues to build for IPTV and faster services, fiber will be more widely adopted further reducing prices. Fiber truly is the fastest data communications medium available and it will grow at an even faster rate as the demand for Internet speed and bandwidth continues. **NV**



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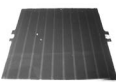
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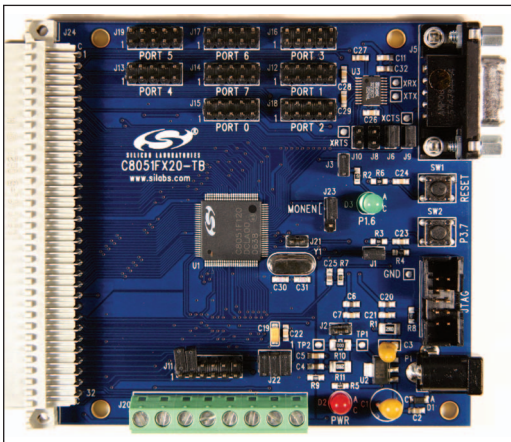
PREVIOUS DESIGN CYCLE COLUMNS have focused on providing you with an in-depth technical view into the Silicon Laboratories C8051F120 microcontroller. All good things must come to an end and this month's installment of Design Cycle will wrap up our look at the C8051F120 microcontroller.

If you've had the time and interest to take in our previous C8051F120 discussions, you have already been introduced to many of the C8051F120's on-chip peripherals. This month's collection of technical speak, C8051F120 C source code, pictures, and graphics will cover the remainder of the C8051F120 peripherals that we have not yet examined.

Up to this point, everything hardware has been based on the electronics you see in Photo 1. The collection of active and passive electronic components surrounding the C8051F120 microcontroller in Photo 1 makes up a Silicon Laboratories C8051F120 Development Board, which is part of a Silicon Laboratories Development Kit. With the assistance of the Silicon Laboratories USB Debug Adapter you see in Photo 2, I can use the C8051F120 Development Board to exercise all of the C8051F120's on-chip peripherals. All of the C8051F120's analog-to-digital converter inputs, comparator inputs, comparator outputs, digital-to-analog converter outputs, general-purpose I/O port pins, voltage reference inputs, voltage reference outputs, capture inputs, PWM outputs, general-purpose timer outputs, counter outputs, and serial ports are available to us on the C8051F120

Development Board by way of pins, screw terminals, a D-shell connector, and a 96-pin expansion

■ **PHOTO 1.** Everything you need to get an understanding of how the C8051F120 and its on-chip peripherals work can be found on this board.



I/O connector. This high accessibility of C8051F120 signals allows me to use a Cleverscope to show you waveforms, logic levels, and voltages that are generated in response to stimuli introduced by the C programming language.

USB is the big thing in personal computers these days. However, as long as microcontroller hardware continues to include on-chip UARTs, RS-232 will live. So, let's begin this month's discussion by putting some frills into the UART code we discussed previously.

UART INTERRUPTED

We initialized and activated the C8051F120's UART0 in the previous Design Cycle column. However, we didn't care to listen for other intelligent electronic devices as we were using UART0 to do all of the talking. So, this time around, we'll add some ears to our UART0 code.

If you're just tuning in, we used the Configuration Wizard 2 application to lay the groundwork for much of the UART0 code we generated in previous Design Cycle discussions. We will continue to use the Configuration Wizard 2 application as we go about enabling and activating the remainder of the C8051F120 peripherals we are yet to encounter. However, there are some things the Configuration Wizard 2 cannot do for us. For example, the Configuration Wizard 2 is not

designed to allocate UART0 transmit and receive buffers in the C8051F120's SRAM area. Generating interrupt handler routines is another task that the Configuration Wizard 2 is not suited for. That leaves us to use our noggins to augment the basic UART0 code that was provided so graciously to us by the



■ **PHOTO 2.** Couple this little bugger with the Keil μ Vision3 8051 C Development Suite and take a journey into the C8051F120's inner spaces.

Configuration Wizard 2 application.

Our goal is to write some C code to implement an interrupt driven RS-232 communications engine using the C8051F120's UART0 as the central hardware component. The first order of business is to allocate transmit and receive buffer space within the C8051F120's SRAM. Here's the code behind the buffer allocation:

```
// size of serial transmission buffer
#define TxBUFLen 8
#define TxBUFMask (TxBUFLen - 1)
// transmission buffer start index
unsigned char TxHead;
// transmission buffer end index
unsigned char TxTail;
// storage for transmission buffer
char xdata TxBuf[TxBUFLen]

// size of serial receiving buffer
#define RxBUFLen 16
#define RxBUFMask (RxBUFLen - 1)
// receiving buffer start index
unsigned char RxHead;
// receiving buffer end index
unsigned char RxTail;
// storage for receiving buffer
char xdata RxBuf[RxBUFLen];
```

The transmit and receive buffers have a few things in common. They both must be allocated in powers of 2. That is, the least significant bit of the buffer length must always be zero. Thus, the transmit and receive buffers are allocated as 2, 4, 8, 16, 32, 64, 128, etc., bytes in length. The reason for this is that we want the transmit and receive buffer mask values to contain a 1 for every buffer location except buffer location zero. For instance, our transmit buffer length (TxBUFLen) is equal to 8 which is 0b1000 (the 0b denotes binary just as 0x represents hexadecimal). The transmit buffer mask value (TxBUFMask) is derived by subtracting 1 from the TxBUFLen value, which results in a TxBUFMask value of 0b0111. Seven transmit buffer locations are represented by 0b0111 with the zero transmit buffer location representing the eighth transmit buffer location. If we break down the creation of the receive buffer mask (RxBUFMask) value, we will end up with 0b1111, which touches the 15 receive buffer locations following receive buffer location zero. You'll get to see how the transmit and receive buffer masks are used when we examine the UART0 interrupt handler code.

As long as we keep our transmit and receive buffer lengths below 256 bytes, we can use eight-bit character pointers to delineate the transmit and receive buffers' beginning (Head) and end (Tail). By incorporating the Head and Tail

in our buffer scheme, both of the transmit and receive buffers can be considered to be circular. Incoming buffer characters are stored in the buffer Tail address and outgoing buffer characters are taken from the buffer Head address. Thus, the Head is always chasing the Tail and the buffer is considered empty when the Head address is equal to the Tail address. Conversely, the buffer is full when the Tail address is one less than the Head address.

To give you a better picture of the receive buffer mechanics, I initialized all of the C8051F120 on-chip peripherals, turned on the UART0 interrupts, and entered a never-ending loop to capture 16 characters I sent from a personal computer running Tera Term Pro. The results are shown in the µVision3 Watch Window I captured for you in Screen Shot 1. By declaring the buffer areas using "char xdata," both of the transmit and receive buffers are allocated in the C8051F120's on-chip 8K XRAM memory area. Since the transmit and receive buffers are so small, we could have also allocated them into the C8051F120's 256-byte SRAM area using "char idata" in the buffer declaration statements.

With the UART initialized to run in eight-bit mode with its interrupts active and the transmit and receive buffers allocated, our next step entails writing the receive interrupt handler. No sweat. Coding the receive interrupt handler is a walk in the park. Here's the receive interrupt handler code:

```
static void com_isr (void) interrupt 4
{
    // RECEIVE INTERRUPT HANDLER
    unsigned char c;
    if (RIO) {
        c = SBUF0;           //read character
        RIO = 0;            //clear interrupt request flag

        //check for end of receive buffer
        if (RxHead + RxBUFLen != RxTail) {
            //put character into buffer
            RxBuf[RxTail++ & RxBUFMask] = c;
        }
    }
}
```

■ **SCREEN SHOT 1.** The 16 characters I keyed into the Tera Term Pro window are shown in the hex dump area beginning at address 0x00000 and ending at address 0x0000F. Note that the debug window points out the beginning address (X:000000) of the receive buffer, which, according to the "X:" is located in the C8051F120's internal XRAM memory.

Name	Value
RxBuf	X:00000000 "0123456789ABCDEF"
[0]	0x30 '0'
[1]	0x31 '1'
[2]	0x32 '2'
[3]	0x33 '3'
[4]	0x34 '4'
[5]	0x35 '5'
[6]	0x36 '6'
[7]	0x37 '7'
[8]	0x38 '8'
[9]	0x39 '9'
[10]	0x41 'A'
[11]	0x42 'B'
[12]	0x43 'C'
[13]	0x44 'D'
[14]	0x45 'E'
[15]	0x46 'F'



MAC0A, and MAC0B Bit Weighting

High Byte								Low Byte							
-1	2 ⁻¹	2 ⁻²	2 ⁻³	2 ⁻⁴	2 ⁻⁵	2 ⁻⁶	2 ⁻⁷	2 ⁻⁸	2 ⁻⁹	2 ⁻¹⁰	2 ⁻¹¹	2 ⁻¹²	2 ⁻¹³	2 ⁻¹⁴	2 ⁻¹⁵

MAC0 Accumulator Bit Weighting

MAC0OVR					MAC0ACC3 : MAC0ACC2 : MAC0ACC1 : MAC0ACC0										
-(2 ⁸)	2 ⁷			2 ²	2 ¹	2 ⁰	2 ⁻¹	2 ⁻²	2 ⁻³		2 ⁻²⁷	2 ⁻²⁸	2 ⁻²⁹	2 ⁻³⁰	2 ⁻³¹

MAC0RND Bit Weighting

High Byte								Low Byte							
*-2	1	2 ⁻¹	2 ⁻²	2 ⁻³	2 ⁻⁴	2 ⁻⁵	2 ⁻⁶	2 ⁻⁷	2 ⁻⁸	2 ⁻⁹	2 ⁻¹⁰	2 ⁻¹¹	2 ⁻¹²	2 ⁻¹³	2 ⁻¹⁴

The com_isr interrupt handler is called when a transmit or receive event occurs. In the case of the receive interrupt handler code, the first thing we do is check the RIO receive interrupt flag. If the RIO flag is set, we simply pull the incoming character from the UART0 buffer, reset the RIO flag, check for a full receive buffer, and if the buffer is available, we stash the incoming character into the next available receive buffer slot. If the receive buffer is full, the character is tossed into the bit bucket.

The transmit interrupt handler code is just as simple:

```
// TRANSMIT INTERRUPT HANDLER
if (TI0)
{
    TI0 = 0; // clear interrupt request flag
    if (TxHead != TxTail) // if characters in buffer
    {
        SBUF0 = TxBuf[TxHead++ & TxBUFMASK]; // transmit a character
        CharInTxBuf = 0; // clear 'CharInTxBuf' flag
    }
    else
    {
        // if all chars tx'd
        SendChar = 0; // clear 'SendChar' flag
    }
}
```

If the transmit interrupt flag (TI0) is set, we immediately clear it and check to see if the transmit buffer is empty. If the transmit buffer contains a character to be transmitted, we

Name	Value
a	0x0020
b	0x0000
c	0x0000
d	0x0000
e	0x0000
f	0x0000
g	0x0020
h	0x0000

■ FIGURE 1. When you compare my 0x4000 to the bit patterns here, it becomes pretty obvious as to how the fractional-to-hex stuff works. Want to load up MAC0A with -0.25? No problem! The hex equivalent is 0xE0. That's -1.0 + 0.5 + 0.25 (0b11100000). Piece of cake.

extract the character from the Head of the transmit buffer and transmit the character by loading it into UART0's SBUF0.

Now is a good time to look at the job that the buffer masks do. Note that we are not

performing any error checking and thus the buffer mask bits are not used to their full potential. Basically, the buffer mask bits are used to make sure that the buffer addressing never leaves the extents of the allocated buffer. In other words, a 16-byte buffer will never correctly recognize a buffer address greater than 15. Remember that address zero completes the 16 bytes.

I've augmented the UART0 interrupt handler routines with some utility routines that pull incoming characters from the receive buffer and push outgoing characters into the transmit buffer. I've provided a complete μ Vision3 project based on the C8051F120's UART0 as a download from the *Nuts & Volts* website (www.nutsvolts.com).

CIPHERING WITH THE C8051F120

That's what Jethro Bodine would call what the C8051F120's MAC (Multiply and Accumulate) unit does. The C8051F120 MAC unit is most useful when the C8051F120 is involved in math-intensive operations such as digital filtering. However, the C8051F120's MAC unit can be used to perform less complicated mathematical operations, as well. Many of the mathematical tasks that a microcontroller gets involved in use signed fractional numbers, as well as integers. The MAC unit can easily handle both.

The C8051F120's MAC unit is very easy to understand and use. The bulk of the MAC unit consists of a pair of 16-bit registers (MAC0AH/MAC0AL and MAC0BH/MAC0BL) in which the values to be multiplied are loaded. The result of the multiplication is pushed into the MAC's 40-bit accumulator. The accumulator can be instructed to sum the incoming multiplication results or clear itself to hold only a single multiplication result. Upon command, the result held in the MAC's accumulator can be shifted left or right by one bit.

Let's do some cipherin' with the C8051F120 MAC. First, we will load the MAC "A" 16-bit register pair with

■ SCREEN SHOT 2. If you match up the MAC source code with the μ Vision3 debug window variables, variable "f" represents the MAC0STA (status) register. The zero contents of MAC0STA indicate that no hard overflow out of the 40-bit accumulator occurred, there was no overflow into the sign bit, the result in the accumulator is not zero, and the accumulator does not contain a negative number.

+0.50. We'll then multiply the value in MAC0A by +0.50. The multiplication is done following the loading of MAC0BL. The fractional values entered into the MAC0A and MAC0B registers are translated in Figure 1. The code for our little MAC fractional multiply operation looks like this:

```
void main()
{
    unsigned int a,b,c,d,e,f,g,h;

    Init_Device();
    SFRPAGE = MAC0_PAGE;
    MAC0CF = 0x0A; // clear accum-fractional mode
    MAC0AH = 0x40; // load +0.50
    MAC0AL = 0x00; // 0x4000 = +0.50
    MAC0BH = 0x40; // load +0.50
    MAC0BL = 0x00; // kicks off multiply operation
    NOP; // multiply happening here
    NOP; // accumulator updated
    NOP; // rounding register updated

    a = MAC0ACC3; // accumulator registers
    b = MAC0ACC2;
    c = MAC0ACC1;
    d = MAC0ACC0;
    e = MAC0OVR; // accumulator overflow register
    f = MAC0STA; // status register
    g = MAC0RNDH; // rounding registers
    h = MAC0RNDL;

    while(1);
}
```

According to Screen Shot 2, the accumulator contains 0x2000. Using Figure 1 as our guide, 0x2000 is equivalent to +0.25. It's really easy to do integers with the C8051F120's MAC unit, too. All we have to do is clear the fractional/integer bit in the MAC0CF register and treat our numbers just like we're used to in the MAC0A, MAC0B, and accumulator registers. Keep in mind that the most significant bits of these registers is the sign bit in integer mode. Here's what MAC integer operation code looks like:

```
void main()
{
    unsigned int a,b,c,d,e,f,g,h;

    Init_Device();
    SFRPAGE = MAC0_PAGE;
    MAC0CF = 0x08; // clear accum-integer mode
    MAC0AH = 0x00; // load +2
    MAC0AL = 0x02; // 0x0002 = +2
    MAC0BH = 0x00; // load +2
    MAC0BL = 0x02;
    NOP;
    NOP; // accumulator updated
    NOP; // rounding register updated

    a = MAC0ACC3; // accumulator registers
    b = MAC0ACC2;
    c = MAC0ACC1;
    d = MAC0ACC0;
    e = MAC0OVR; // accumulator overflow register
    f = MAC0STA; // status register
    g = MAC0RNDH; // rounding registers
    h = MAC0RNDL;

    while(1);
}
```

We all know what the answer is. However, the answer (4) will be situated in the accumulator's MAC0ACC0 register with the remaining MAC0ACCX registers holding zero values (0x0004). I've included both the fractional and integer code we just looked at in the source code download package so you can get hands-on with the C8051F120's MAC unit.

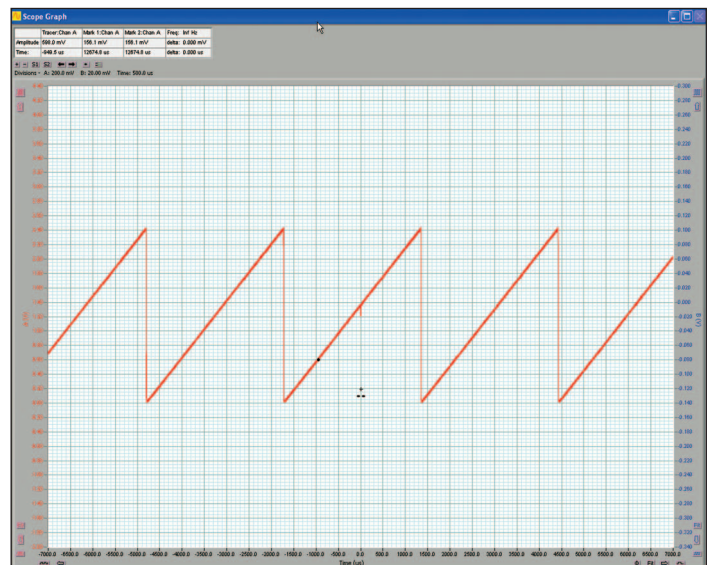
MAKING WAVE(FORM)S WITH THE C8051F120 DAC

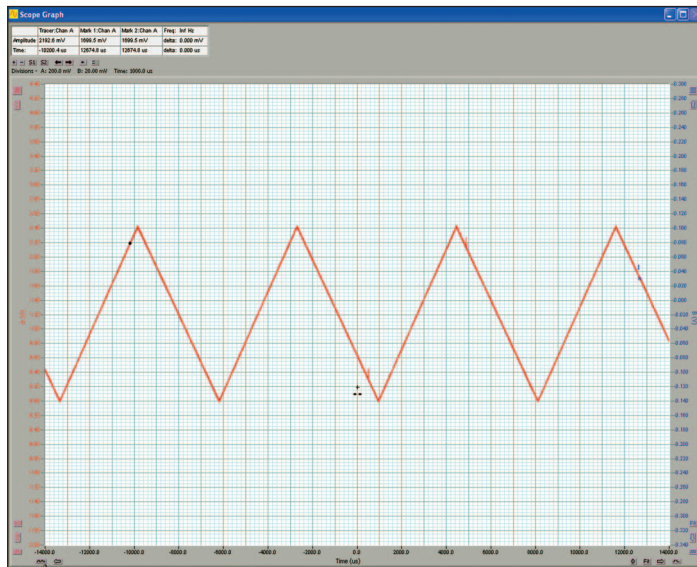
The C8051F120 contains a pair of on-chip digital-to-analog converters and before we're done, we'll put them both to use. I could exercise the C8051F120's DAC by entering some values into the DAC registers and reading out the resultant voltages. That would be boring as heck. So, let's create some waveforms using the C8051F120's DAC0.

The very first thought that came to my mind was to simply sweep DAC0 from 0.00 to its maximum voltage value. The C8051F120 has an on-chip +1.2V voltage reference that can be used to feed the comparators, the analog-to-digital converters, and the digital-to-analog converters. An x2 buffer/amplifier boosts the C8051F120's on-chip reference voltage to +2.4V. Thus, I can sweep the 12-bit digital-to-analog converters between 0.0V (0x000) and +2.4V (0xFFFF) by simply sweep loading the DAC data registers. It then occurred to me that if I performed this sweep with reference to a timebase, I could create a sawtooth waveform. Let's write some DAC code to see if I can indeed create a crude sawtooth waveform by sweeping DAC0 with some rhythm.

I used the Configuration Wizard 2 application to help

■ **SCREEN SHOT 3.** I wasn't in "scientific mode" when I coded up the sawtooth code. So, the frequency of the waveform is solely SWAG and was chosen to make a good picture to show you.





me get started with the DAC0 by having it generate the DAC0 initialization code you see here:

```
void DAC_Init()
{
    SFRPAGE = DAC0_PAGE;
    // update DAC on Timer2 overflow-enable DAC
    DAC0CN = 0x98;
}
```

I have the option of updating the DAC0 data registers with a write to DAC0H or on an overflow of Timers 2, 3, or 4. Random chance has worked in our favor as I am able to load my DAC0 sweep values into the DAC0 data registers on every overflow of what is now our timebase, Timer 2. I won't have time to poll for a Timer 2 overflow as I will compromise the resultant waveform. So, I'll turn on the Timer 2 interrupt mechanism and trip the interrupt mechanism on every Timer 2 overflow. Once tripped, I'll execute the code contained within the tmr_isr interrupt handler:

■ **SCREEN SHOT 4.** To get this triangle waveform, I simply added a phase variable that ramps the sawtooth DAC0 data register values up and down.

```
static void tmr_isr (void) interrupt 5
{
    //Sawtooth Code

    if(++low_counter == 0)
    {
        if(++high_counter == 0x10)
            high_counter = 0x00;
    }
    DAC0L = low_counter;
    DAC0H = high_counter;
}
```

The Sawtooth Code simply increments the low_counter variable until it overflows from 0xFF to 0x00. On every low_counter overflow, the high_counter variable is incremented until it overflows from 0x00 to 0x10. Thus, the maximum count that the low_counter and high_counter register pair can contain is 0xFFFF, which is the maximum value we can push into the DAC0 data registers.

I used the SWAG method of choosing the Timer 2 overflow value. I just kept adjusting the Timer 2 reload value until I got a nice trace on the Cleverscope. The Timer 2 code that you'll get in the download package is shown here:

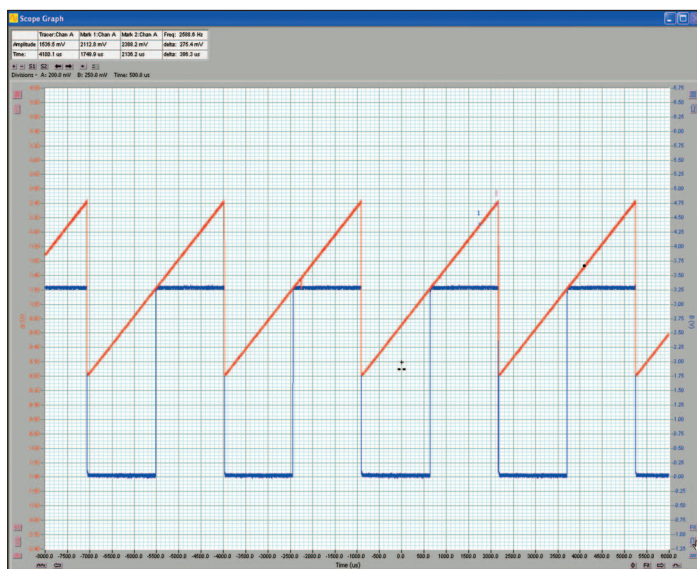
```
SFRPAGE = TMR2_PAGE;
TMR2CN = 0x04; //enable Timer 2
TMR2CF = 0x08; //SYSCLK is timer source clock
//reload Timer 2 on overflow to 0xFF4C
RCAP2L = 0x4C;
RCAP2H = 0xFF;
```

With all of the DAC0 and Timer 2 initialization and interrupt code in place, all that's needed to generate a sawtooth wave is this:

```
void main()
{
    Init_Device(); // init the chip peripherals
    low_counter = 0x00; // init the waveform counters
    high_counter = 0x00;
    while(1); // saw logs
}
```

While I was tinkering with the sawtooth wave you see in Screen Shot 3, I figured I could just as easily put a triangle waveform on the Cleverscope graph window. All I

■ **SCREEN SHOT 5.** This is an example of how to modulate a square wave using a sawtooth wave and a comparator. All of this is done by the C8051F120 peripherals. DAC0 provides the sawtooth waveform and DAC1 is acting as a reference voltage for Comparator 1. The base reference voltage is provided by the C8051F120's on-chip reference voltage generator.



have to do is count down when the DAC0 data registers get loaded with 0xFF instead of resetting the DAC0 data registers to 0x000 at that point. As it turned out, to get a triangle wave to appear on the Cleverscope graph window, I only had to add some triangle code to the Timer 2 interrupt handler:

```
static void tmr_isr (void) interrupt 5
{
    //Triangle
    if(phase == 0)
    {
        if(++low_counter == 0)
        {
            if(++high_counter == 0x10)
            {
                phase = ~phase;
                high_counter = 0x0F;
                low_counter = 0xFF;
            }
        }
    }
    else
    {
        if(--low_counter == 0xFF)
        {
            if(--high_counter == 0xFF)
            {
                phase = ~phase;
                high_counter = 0x00;
                low_counter = 0x00;
            }
        }
    }
    DAC0L = low_counter;
    DAC0H = high_counter;
}
```

The triangle interrupt handler code depends on the value of the phase variable to determine whether it needs to increment or decrement the value being fed to the DAC0 data registers. This country boy guessed right again as you can see in the Cleverscope display shown in Screen Shot 4. We're not done with DACs yet. I've got another idea.

DARE TO COMPARE

What if I fired up DAC1 and set it to generate +1.2V by writing 0x7FF to the DAC1 data registers, used the DAC1 voltage as a reference voltage for Comparator 1, and fed Comparator 1 with the sawtooth wave from DAC0? I should get a square waveform that is modulated by the Comparator 1 reference voltage versus the voltage of the sawtooth waveform. Let's code it up and see if I'm right.

■ **SCREEN SHOT 6.** You can see that as I increase Comparator 1's reference voltage, the high portion time of the Comparator 1 output square waveform grows smaller. By sweeping DAC1, we can create a PWM signal at the output of Comparator 1.

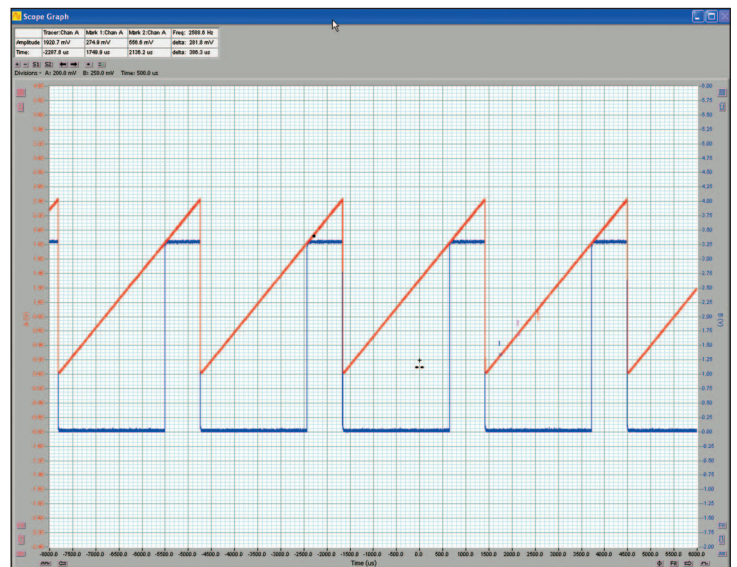
Once again, I let the Configuration Wizard 2 application do the dirty work of initializing Comparator 1:

```
void Comparator_Init()
{
    unsigned int i;
    SFRPAGE = CPT1_PAGE;
    CPT1CN = 0x80; // enable Comparator 1
    for (i=0;i<60;i++) // Wait 20us for init
        ;
    CPT1CN &= ~0x30; // clear the interrupt flags
    CPT1MD = 0x30; // set mode to fastest
}
```

DAC1 does not need to do anything fancy. So, I simply enabled it and it will only update its data registers on a write to DAC1H (done by loading DAC1CN (DAC1 Control Register with 0x80). Now all I need to do is turn the sawtooth waveform loose and write the +1.2V voltage value to the DAC1 data registers:

```
void main()
{
    Init_Device();
    low_counter = 0x00;
    high_counter = 0x00;
    SFRPAGE = DAC1_PAGE;
    DAC1L = 0xFF;
    DAC1H = 0x07;
    while(1);
}
```

Take a look at Screen Shot 5. The modulated square wave is actually the output of Comparator 1. As the sawtooth wave voltage passes through +1.2V, the Comparator 1 output trips from low to high and remains high as long as the sawtooth wave voltage is above +1.2V, which is what we dialed into Comparator 1 as its reference voltage. If I load DAC1's data registers with a larger value, Comparator 1's reference voltage will also



increase accordingly. The result is the square waveform you see in Screen Shot 6. The DAC1 data registers are loaded with 0xBFF, which forces Comparator 1 to trip at 1.80V.

If you're wondering why the Comparator 1 output is larger in voltage magnitude than the sawtooth waveform,

the answer is simple. Comparator 1 can swing its output from 0.00V to just a bit below +3.3V as its output is referenced to the C8051F120's VDD, which happens to be +3.3V. DAC0, which is supplying the sawtooth waveform, is referenced to the C8051F120's +2.4V on-chip voltage reference, which is being

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SOURCES

■ **Silicon Laboratories** (www.silabs.com) — C8051F120, C8051F120 Development Board

■ **Keil** (www.keil.com) — Keil uVision3 C Compiler

■ **Saelig** (www.saelig.com) — Cleverscope

supplied to DAC0 via the x2 buffer/amplifier.

CHECKED OUT

You're ready to roll with your own C8051F120 applications as you're now "checked out" on the C8051F120 and its on-chip peripherals. If you're wondering about the absence of analog-to-digital converter coverage, here it is courtesy of the Configuration Wizard 2 application:

```
void ADC_Init()
{
    SFRPAGE    = ADC0_PAGE;
    ADC0CN     = 0x80;    // enable ADC0
}
```

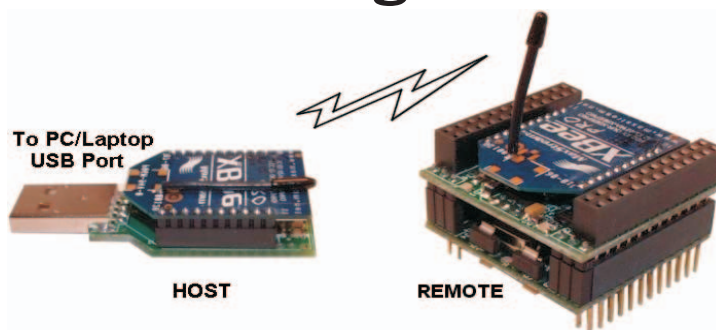
Use the Configuration Wizard 2 application to choose your analog-to-digital converter trigger method and write some simple code to poll for and fetch the analog-to-digital converter result. That's all you need to read voltages at the C8051F120's AN0 input. Using the C8051F120's analog-to-digital converter in basic mode is no different than using any other microcontroller's analog-to-digital converter.

The key to C8051F120 application success lies with the Configuration Wizard 2 application and the Keil µVision3/Silicon Laboratories development suite. If you have control over the aforementioned items, you can easily add the C8051F120 to your Design Cycle. **NV**

CONTACT THE AUTHOR

■ **Peter Best** can be reached via email at peter@nerdvilla.com.

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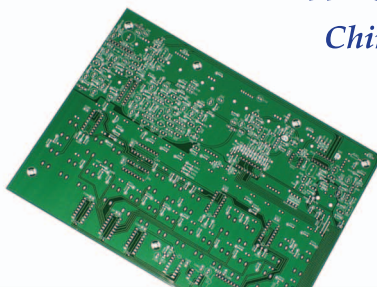
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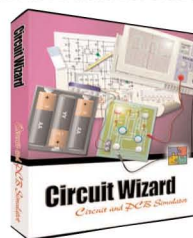
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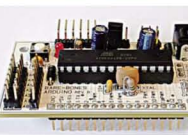
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All questions and answers should be sent by email to forum@nutsvolts.com All *diagrams* should be computer generated and sent with your submission as an attachment.

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- ③ Problem Solving
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>>> QUESTIONS

What technology is used in the customer sensors above the grocery store doors to detect an approaching customer? Are these units available new or surplus anywhere?

#06071

Bert Henscheid
via email

I need to interface a GPS engine serial data out to two different devices. I would also like to isolate the three units from each other. Can the serial data output from a GPS engine drive two opto-isolators directly, and if so, would the output of the GPS be connected directly to the isolator input? Next, are there opto-isolators that have one input and two or more outputs?

#06072

Charlie Willwerth
Saint Augustine, FL

I would like to do some kernel debugging and the software I am using requires the use of one PC to monitor another PC. In the past, this would be done using a null modem cable between the two serial ports. Now with only USB ports, I am wondering how to create a null modem cable. One thought would be to get two USB to serial port adapters and hook a null modem cable between them. I'm not sure that would work, and even if it did, a more direct approach and

explanation would be much appreciated.

#06073

John Huseby
via email

How can I vary the 60 Hz line voltage frequency by very small amounts? I have an expensive electric clock that keeps very bad time. I'm thinking if I could adjust the frequency going to the clock, I could correct this problem. Either a commercial piece of equipment or a schematic would be useful.

#06074

Richard Flaws
Oswego, IL

I need a simple circuit that would supply a two second on pulse and be off for 10 to 12 minutes. It should repeat this cycle over and over again. The on pulse would drive a 3 VDC relay. This would be powered from a 5 VDC power supply. Any ideas?

#06075

John
via email

Is the new Microsoft operating system Vista back compatible? I have many programs on Astronomy from Windows 98 vintage, on floppies, that cannot be duplicated.

#06076

Lyle A. Nelson
Devils Lake, ND

How hard would it be to make my APC UPS more usable during extended power outages by using 12 volt Optima

via email

[#3072 - March 2007]

I built an ATME[®]L-based stepper controller that sent the step commands through four power MOSFETs that connected directly to the coils of a "four volt, 1.2 amp/phase" unipolar stepper. It was an inexpensive motor but it worked great – good torque and speed and started right back if stalled. I bought more of the "same" motor – it had a different label and didn't work at all – stalled, shook, and no torque. I got several different motors from different companies, all with a rating of 4-5 volts at 1-1.2 amps (I'm using a switching supply rated five volts, 3.5 amps) and they all respond differently. None work as well as the first (and cheapest) motor. The MOSFETs have protection

diodes and I tried adding diodes to the power lines – no change. I bought a commercial controller with a motor rated 12 volts, .4 amps, which turned out to be a 12-volt version of my original motor, and it worked very well.

The other motors run better with that controller, which has variable current, but still vary in performance. I can't (nor can the motor company) figure out why there is so much variation in output with motors with the same ratings. Is there some way I can get the rated power out of these motors without spending a fortune? Is there another motor rating or spec that I can use to judge these motors?

Stepper motors are rated by volts/amps per phase, phase inductance, steps per revolution, number of phases, detent, and holding torque. A quick way to tell motor performance at given current and voltage per phase is to compare the holding torque since it is the maximum torque the motor can develop at low speeds and the highest load. Another important

parameter is winding inductance; the lower, the better for high speed performance, since a low inductance allows winding current to build up faster. From what you are describing, you may have an incorrect phasing sequence or system resonance.

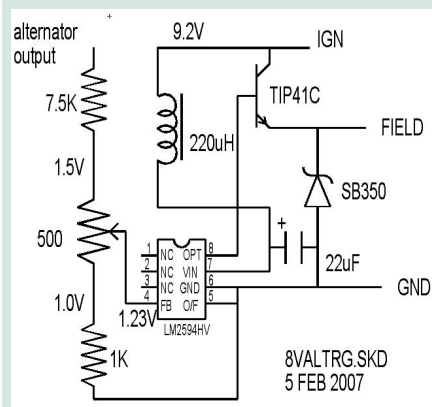
Another possibility is a difference in phase inductance or not enough current, or demagnetized (overheated) motors or winding shorts, just to give you the starting points. Keep in mind that torque is roughly proportional to current in the linear region.

Excellent references are Stepping Motor Basics at EAD Motors (www.eadmotors.com), and the best one I have seen is Jones on Stepping Motors at University of Iowa (www.cs.uiowa.edu/~jones/step). There are also other resources at Camtronics, Inc. (dynamometer testing). If you need to get into the more sophisticated five-phase systems, there is Oriental Motors at (www.orientalmotor.com/products/ac-dc-step-motors/).

Walter Heissenberger
Hancock, NH

[#2075 - February 2007]

I need an alternator circuit that will allow me to charge an eight-volt lead-acid battery in a WWII army vehicle using a standard automobile alternator.



#1 Newer automotive alternators have built-in regulators, so you will have to either remove the internal regulator or find an older one that requires an external regulator. On Delco alternators, you can tell if the regulator is internal or external by the connector. If the blades are parallel, the regulator is internal. On

alternators that use an external regulator, the two blades are at right angles. As I recall, the blade on the right connects to the field; the other is for the idiot light. This circuit is similar to one I sent in earlier. The LM2594 is a PWM regulator operating at 150 kHz. The diode is a three amp Schottky to catch the backswing of the inductance of the field winding. The TIP41C is a TO-220 transistor and should not need a heatsink because it is used as a switch. The eight volt battery is actually 8.4 volts and needs 9.2 volts to charge.

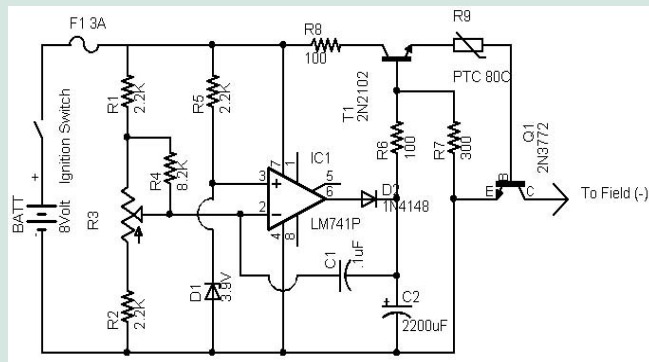
Russell Kincaid
Milford, NH

in turn, controls the alternator output. This URL provides details and a schematic for building your own simple adjustable regulator: **www.amsterdamhouseboats.nl/voltage_regulator.htm**

A modification to the circuit is needed to operate with an eight volt battery. The 6.2 volt zener diode and the 3.3K resistor in series with it need to be changed to a 3.9 volt zener and a 2.2K resistor. The 3.3K resistors in series with the 1K pot also need to be changed to 2.2K — see the schematic below which includes the modifications.

Ed Schick
Harrison, NY

#2 Most alternators have a built-in regulator, which must be removed and replaced with one designed for eight volts to charge your eight volt battery. The regulator controls the current to the field winding of the alternator which,



[#3074 - March 2007]

I have been told by someone whose judgement and knowledge I normally trust that malware exists that will write itself into the EEPROM on a hard drive, normally accessible only by the drive manufacturer, used to store such things as a bad sector map, natural-tological translation tables, etc. If this is true, are there third-party utilities that can detect and delete such malware? Otherwise, must it be returned to the manufacturer to be "cleaned?"

The data sheets for several EEPROMs — especially the Flash variety — show a serious possibility that any malware that gets into the EEPROM can set a protection flag that makes it irreversible and uneraseable.

An obvious clue to such malware would be a pop-up message saying "a Flash update is available for your (brand) computer."

In this situation, if it ain't broke, don't break it. The message sounds like a good idea without giving any clue as to why it would be, when it is

certainly a dangerous procedure to do a Flash update with a high likelihood of failure; the consequence will certainly render the updated device DEAD.

A less obvious source of Flash malware is DRM, and the DMCA forbids testing DRM for anything including viruses. Sure enough, in November 2005, a major record label was caught putting a dangerous virus on their retail music CDs which kills the CD drive. A dead burner, or one that often burns "coasters" may have been infected. I've seen a burner go dead right out of the box with a "Flash update." I've also seen one noisily grind scratches into a CD with its laser lens.

Flash updates and DRM are avoidable. If by some other means the Flash is corrupted, since it is irreversible, there is no software solution. In the case of a hard drive, it either kills the drive dead or infects it with a permanent virus, and in the worst case the virus does nothing harmful except undetectably spy on you, otherwise it becomes an obviously bad drive. Spyware may create a

"tumor partition" (I don't know exactly what this is called) which cannot be removed and may be indistinguishable from many megabytes of bad sectors. I'd assume it contains a record of everything you do on the computer.

There is really no software defense against any kind of malware but there is one surefire hardware defense since the beginnings of home computers: write protected media.

In the past, this was a hole in a floppy or tape which could be covered to switch off the possibility of unauthorized writing to the media. This is notably absent from much modern media, such as hard drives. Non-burning CD-ROM drives are well protected, and SD Flash cards are reasonably protected. Protecting EEPROM or Flash firmware may require significant hardware modification, the simplest of which may be replacing the firmware in a non-eraseable ROM. Perhaps only the design engineer of your drive knows the full details.

William Como
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Programmable DC Electronic Loads

The CSI 3700 series electronic loads are single input programmable DC electronic loads that provide a convenient way to test batteries and DC power supplies. It offers constant current mode, constant resistance mode and constant power mode. The backlight LCD, numerical keypad and rotary knob make it much easier to use. Up to 10 steps of program can be stored.



Model	CSI3710A	CSI3711A
Input Voltage	0-360V DC	0-360V DC
Input Current	0-30A DC	0-30A DC
Input Power	0-150W	0-300W

CSI3710A: \$349.00

CSI3711A: \$499.00

ESD Safe CPU Controlled SMD Hot Air Rework Station

The heater and air control system are built-in and adjusted by the simple touch of the front keypad for precise settings. Temperature range is from 100°C to 480°C / 212°F to 896°F, and the entire unit will enter a temperature drop state after 15 minutes of non-use for safety and to eliminate excessive wear.



Item# **CSI825A++**

- CPU Controlled
- Built-in Vacuum System
- Temperature Range: 100°C to 480°C / 212°F to 896°F
- 15-Minute Stand-By temperature "sleep" mode
- Power: 110/120 VAC, 320 W maximum

Details at Web Site

> Soldering Equipment & Supplies

**Sale
\$149.00!**

Protek 100,000 Count Programmable Data Logging DMM

A power house DMM with 100,000 count accuracy and a built-in data logger that will help you find intermittent problems and monitor equipment while you are busy working on other jobs. The D620 can record and store in it's own internal memory up to 37,300 time stamped data values in all functions by simply pressing a button.

- True RMS measurements for AC
- RS-232C interface with personal computer.

**Special
\$169.00!**

Item# **PROTEK D620**



Details at Web Site > Test Equipment > DIGITAL MULTIMETERS

Dual Output DC Bench Power Supplies

High stability digital read-out bench power supplies featuring constant voltage and current outputs. Short-circuit and current limiting protection is provided. SMT PC boards and a built-in cooling fan help ensure reliable performance and long life.

- Source Effect: $5 \times 10^{-4} = 2\text{mV}$
- Load Effect: $5 \times 10^{-4} = 2\text{mV}$
- Ripple Coefficient: $< 250\text{uV}$
- Stepped Current: 30mA +/- 1mA

**HOT
ITEM!**

All 3 Models have a 1A/5VDC Fixed Output on the rear panel

CSI3003X-5: 0-30v/0-3amp 1-4: **\$105.95** 5+: **\$99.50**

CSI5003X5: 0-50v/0-3amp 1-4: **\$114.95** 5+: **\$109.00**

CSI3005X5: 0-30v/0-5amp 1-4: **\$119.00** 5+: **\$114.00**

Details at Web Site > Test Equipment > Power Supplies



**As Low As
\$99.50!**

Triple Output Bench Power Supplies

with Large LCD Displays

- Output: 0-30VDC x 2 @ 3 or 5 Amps & 1ea. fixed output @ 5VDC@3A
- Source Effect: $5 \times 10^{-4} = 2\text{mV}$
- Load Effect: $5 \times 10^{-4} = 2\text{mV}$
- Ripple Coefficient: $< 250\text{uV}$
- Stepped Current: 30mA +/- 1mA
- Input Voltage: 110VAC



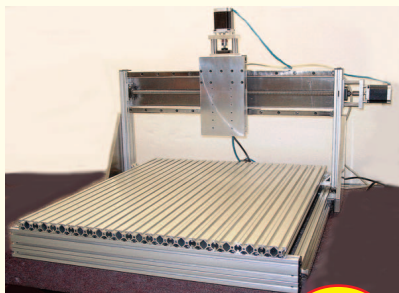
CSI3003X3: 0-30VDCx2 @3A **\$188.00** 5+: **\$183.00**

CSI3005XIII: 0-30VDCx2 @5A **\$239.00** 5+: **\$229.00**

Details at Web Site > Test Equipment > Power Supplies

CNC9000 Motion Control Machine

- Z, X and Y Axis.
- Motor Type: Steppers, Nema 23 size motor mounts on all axes. 277 Oz/in torque.
- Travel: X-22" Y-24" Z-4.5"
- Footprint (overall size not including motors): 34" x 34.75" x 21.75"
- Table top size: 32" x 26"
- ABBA Brand Ball screws and linear rails and trucks on all axis
- 5mm per turn pitch lead screws.
- Direct drive motor coupling on all axis
- Using 3 each CW230 Stepper Motor controllers and a 300watt power supply at 36 Volts.
- Tested Tolerance on 6061 aluminum plate with .125 carbide endmil (0.001) 2"x2"x.025" Using a Porter Cable router.
- Standard (Feed rate of 50 inch per minute with stepper motors)
- Made of 6061 Aluminum except rails, trucks, ball screws and fasteners. Steel and other materials.



**HOT
NEW
ITEM!**

Our Custom Designed and Manufactured CNC Machine comes complete with all Stepper Motors, Controllers and Power Supply. Features NOT found on the competition!

**Item# CNC9000
\$2995.00**

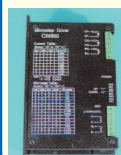
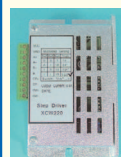
Details at Web Site > Motion Control > Linear Motion

Stepper Motors

Part #:	Motor Frame Size:	Holding Torque:	Price:
42BYGH404	NEMA 17	3.4kg.cm/47oz.in	\$17.95
57BYGH207	NEMA 23	8kg.cm/111oz.in	\$24.95
57BYGH303	NEMA 23	15kg.cm/208oz.in	\$29.95
57BYGH405	NEMA 23	20kg.cm/277oz.in	\$34.95
85BYGH350B-03	NEMA 34	48kg.in/665oz.in	\$79.95
85BYGH350C-03	NEMA 34	63kg.cm/874oz.in	\$119.95



Stepper Motor Controllers 2 Phase Microstepping Stepper Motor Driver (Bi-polar & Unipolar Motors)



Part #:	Dimensions:	MicroStep:	Price:
XCW220	100mm x 61mm x 19mm	1(200), 1/2(400), 1/4(800), 1/8(1600)	\$39.95
CW220	99mm x 65mm x 30mm	1/2(400), 1/8(1600)	\$49.95
CW230	115mm x 72mm x 32mm	1(200), 1/2(400), 1/4(800), 1/8(1600), 1/16(3200), 1/32(6400), 1/64(12800)	\$59.95
CW250	140mm x 94mm x 45mm	1(200), 1/2(400), 1/8(1600)	\$69.95
CW860	147mm x 97mm x 30mm	1(200), 1/2(400), 1/4(800), 1/8(1600), 1/16(3200), 1/32(6400), 1/64(12800), 1/128(25600), 1/5(1000), 1/10(2000), 1/25(5000), 1/50(10000), 1/125(25000), 1/250(50000)	\$119.95

Protek

Protek 2.0 & 2.9GHz Field Strength Analyzers

- Frequency Range : 100KHz ~ 2900MHz (2060MHz for 3201N)
- WFM/NFM/AM/SSB modulated signals may be measured.
- Sweep Trigger Mode: Free Run, Single Run, Continuous Wave, Squelch Run
- Sweep Speed: 500 to 2000msec
- PLL tuning system for precise frequency measurement and tuning
- Built-in Frequency Counter
- RS232 interface



**New
Rev. Now
Available**

Item#s 3290N & 3201N

Details at Web Site

> Test Equipment > RF Test Equipment

Special

\$1750.00 (for 3290N)

\$1329.00 (for 3201N)

Digital Storage Oscilloscope Module



PC based Digital Storage Oscilloscope, 200MHz 5GS/s equiv. sampling USB interface

Convert any PC with USB interface to a high performance Digital Storage Oscilloscope. This is a sophisticated PC basedscope adaptor providing performance compatible to mid/high level stand alone products costing much more! Comes with two probes.

Details & Software
Download at Web Site

**Price
Breakthrough!**

> Test Equipment > Oscilloscopes/Outstanding Prices

Item# 200DSO Only \$819.00

SONY Super HAD CCD Color Weatherproof IR Cameras

- Day & Night Auto Switch
- Signal System: NTSC
- Image Sensor: 1/3" SONY Super HAD CCD
- Horizontal Resolution: 480TV lines
- Min. Illumination: 0Lux

Item# VC-827D: **\$132.00**

**SONY
Super HAD
CCD™ equipped
camera's feature dra-
matically improved
light sensitivity**

SONY Super HAD CCD B/W Weatherproof IR Camera

- Day & Night Auto Switch
- Signal System: EIA
- Image Sensor: 1/3" SONY Super HAD CCD
- Horizontal Resolution: 420TV lines
- Min. Illumination: 0Lux

Item# VC-317D: **\$59.50**

Details at Web Site

SONY Super HAD CCD Color Camera

- Weather Proof
- Signal System: NTSC
- Image Sensor: 1/4" SONY Super HAD CCD
- Horizontal Resolution: 420TV lines
- Min. Illumination: 1Lux/F1.2

Item# VC-805: **\$53.95**

> Miniature Cameras(Board,Bullet,Mini's, B/W, Color)

SONY Super HAD CCD Color Weatherproof IR Camera

- Day & Night Auto Switch
- Signal System: NTSC
- Image Sensor: 1/4" SONY Super HAD CCD
- Horizontal Resolution: 420TV lines
- Min. Illumination: 0Lux

Item# VC-819D: **\$62.50**



Outdoor Color Speed Dome Camera

- 1/4" SONY Exview CCD
- 768(H) x 494(V) effective pixels
- Horizontal Resolution: 480TV lines
- Up to 80 preset points
- Line scanning
- Continuous 360° horizontal rotation
- Vertical rotation: 0-100°
- RS485 control interface
- Min. Illumination: 0.1Lux (color) / 0.001Lux (B&W)

Item# VC-EX861
\$899.00



Details at Web Site

> Miniature Cameras(Board,Bullet,Mini's, B/W, Color)

Shown with optional wall mount



**480
TV Lines
Resolution**



**480
TV Lines
Resolution**

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programming was fun?**



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easy programming,
simplicity is
power!**



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